

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE  
BEFORE THE BOARD OF PATENT APPEALS AND INTERFERENCES**

Appellants : MARK J. LEVINE et al.

Serial No.:10/730,459 : HYDROENTANGLING USING A FABRIC  
HAVING FLAT FILAMENTS

Filed : DECEMBER 8, 2003

Examiner : Andrew T. Piziali

Art Unit : 1794

Confirmation No. : 2911

745 Fifth Avenue  
New York, NY  
10151

January 5, 2011

**APPEAL BRIEF**

**MAIL STOP APPEAL BRIEF- PATENTS**

Commissioner for Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450

Dear Sir:

Pursuant to the Final Rejection by the Examiner dated August 5, 2010,  
Appellant's attorneys submit this Appeal Brief.

### **REAL PARTY IN INTEREST**

The real party in interest is Albany International Corp., 1373 Broadway, Albany, NY 12204, to which Appellants have assigned all interest in, to, and under this application by virtue of the assignment recorded on April 14, 2003 at reel 13956, frame 908 of the assignment records of the United States Patent and Trademark Office.

### **RELATED APPEALS AND INTERFERENCES**

Upon information and belief, the undersigned attorney does not believe that there is any appeal or interference that will directly affect, be directly affected by, or have a bearing on the Board's decision in the pending appeal.

### **STATUS OF THE CLAIMS**

The Application was filed with claims 1-30 on December 8 2003, and assigned Application Serial No. 10/730,459.

#### *The First Round of Prosecution*

On September 19, 2005, the Examiner issued a complex Requirement for Restriction Election between Five Species Groups (I-V) with 24 species in each group to which Appellants filed a response on October 21, 2005 and elected, without traverse, Species Groups 1-4 and Species 2 from Group 5, claims 1, 2, 4, 7-11, 17-19, 23 and 25-27.

In the first Office Action on the merits, dated December 21, 2005, the Examiner rejected claims 1, 2, 4, 6-8, 13, 14, 23, 25-27, and 30 as anticipated by one or more of U.S. Patent Nos. 3,110,905 to Rhodes ("Rhodes"), 4,595,627 to Steinman ("Steinman"), 5,883,022 to Elsener ("Elsener"), 5,498,468 to Blaney ("Blaney"), and 4,345,730 to Leuvelink ("Leuvelink"). The Examiner rejected claim 13 under 35 U.S.C. § 103(a) as unpatentable over Blaney

In response to the first Office Action dated March 23, 2006, Appellants filed a response amending claims 1, 2, 4, 6-8, 13, 14, 23, 25-27 and 30 to recite a hydroentangling device in combination with a hydroentangling support fabric and traversing the Examiner's rejections.

The Examiner then issued a Final Office Action dated May 30, 2006 maintaining the rejections of claims 1, 2, 4, 6-8, 13, 14, 23, 25-27 and 30 under 35 U.S.C. §102(b) and §103 over Blaney. Additionally, the Examiner rejected claims 1-2, 4, 6, 23, 25-27 and 30 under 35 U.S.C. § 103(a) as unpatentable over Rhodes, in view of U.S. Patent No. 6,060,145 to Smith ("Smith"). Finally, the Examiner rejected claims 1-2, 4, 6-8, 13, 23, 25-27 and 30 under 35 U.S.C. § 103(a) as unpatentable over U.S. Patent No. 5,142,752 to Greenway ("Greenway") in view of Leuvelink.

Appellants filed a response under 35 U.S.C. § 1.116, with no amendment.

The Examiner then issued an Advisory Action on August 9, 2006.

*The Second Round of Prosecution*

The Appellants responded with a Request for Continued Examination dated on August 29, 2006, along with a submission amending claim 1 to recite "said hydroentangled nonwoven product being formed on and thereafter removed from said support fabric."

The Examiner issued a non-final rejection on January 18, 2007, entering the amendment of August 29, 2006 and rejecting all pending claims. Claims 1, 2, 4, 6-8, 13, 14, 23, 25-27 and 30 were rejected over 35 U.S.C. §§103 and 112. The Examiner reasserted the prior rejections as well.

On April 11, 2007 Appellants representative held a telephonic interview with the Examiner to discuss the rejections, including those under 35 U.S.C. §§101 and 112 .

Appellants replied on April 13, 2007 with amending the claims to include "a hydroentangling support fabric ... said support fabric comprising flat filaments" and traversing the rejections."

On May 31, 2007, the Examiner responded with a Final Office Action withdrawing the rejections overs Blamey but repeating his remaining rejections. The Appellants responded with a minor After-Final Amendment dated September 5, 2007 (e.g.: Claim 1: A hydroentangling support fabric [in combination with] for use in a hydroentangling device [usable] for the production of a hydroentangled nonwoven product, said support fabric comprising flat filaments.")

The Examiner issued an Advisory Action on September 13, 2007 refusing the enter the amendment on the basis that "the claims are drawn to a hydroentangling

support fabric rather than a hydroentangling device in combination with a hydroentangling support fabric, [which] raises new issues that would require further consideration and/or search.”

*The Third Round of Prosecution*

In response, Appellants filed a Request for Continued Examination on September 27, 2007.

The Examiner then issued a non-final rejection on October 15, 2007, entering the amendment of September 5, 2007. Claims 1-2, 4, 6, 23 and 25-27 were rejected under 35 U.S.C. §§102 or 103 over Rhodes. Claims 1-2, 4, 6, 23 and 25-27 were also rejected under 35 U.S.C. §§102 or 103 over Steinman, and again over Elsener, and yet again over Leuvelink. The Examiner also reasserted rejections of claims 1, 6, 13-14, 23, 25-27 and 30 under 35 U.S.C. § 103(a) over U.S. Patent No. 5,142,752 to Greenway (“Greenway”) in view of Leuvelink.

On December 12, 2007, Appellants’ representatives held another telephonic interview with the Examiner discussing all the rejections. As the Examiner reported in his interview summary: “Discussed proposed amendments to the claims. Discussed amending the claims to be drawn to an endless woven fabric. The examiner indicated that the proposed amendment may overcome the current art but that further consideration would be necessary.”

In response, Appellants filed an amendment under 35 U.S.C. § 1.121, amending claim 1 to recite that “said support fabric is in a continuous loop or made endless.”

The Examiner then issued a Notice of Non-Compliant Amendment on April 21, 2008 based on improper status identifiers, which Appellants then filed a response on May 5, 2008.

On July 3, 2008, the Examiner issued a Final Office Action, rejecting claims 1, 2, 4, 6-8, 13, 23 and 25-27 under 35 U.S.C. §112, second paragraph, alleging, despite the interview, that the terms were indefinite because the distinction between a continuous loop fabric and an endless fabric is unclear. Claims 1, 2, 4, 6-8, 13, 23 and 25-27 were newly rejected under 35 U.S.C. 102(b) as anticipated by or, in the alternative, under 35 U.S.C. 103(a) as obvious over U.S. Patent No. 5,857,497 to Gaisser (“Gassier”). Despite the Examiner’s

tentative agreement on the claim language during the interview, the Examiner reasserted the rejections of claims 1-2, 4, 6, 13, 23 and 25 to 27 are rejected under 35 U.S.C. § 103(a) over U.S. Patent No. 5,142,72 to Greenway in view of U.S. Patent No. 4,345,730 to Leuvelink, alleging the claims recited “an intended use.” The Examiner also rejected claims 1-2, 4, 6, 23 and 25-27 are rejected under 35 USC § 103 (a) over U.S. Patent No. 5,883,022 to Elsener (“Elsener”) in view of U.S. Patent No. 3,884,630 to Schwartz (“Schwartz”) or U.S. Patent No. 4,104,814 to Whight (“Whight”).

On October 8, 2008, the Appellants filed a Response arguing the rejections. Appellants again referred the Examiner to the Specification, which explained the terms “continuous loop or made endless.” The Appellants also amended the claims to recite “A hydroentangling apparatus... comprising a hydroentangling support fabric.”

The Examiner issued an Advisory Action on October 8, 2008, stating among other things that the amendment raised new issues..

In response, Appellants filed a Request for Continued Examination on October 24, 2008.

*The Fourth Round of Prosecution*

On January 8, 2009, the Examiner issued a non-final rejection and included a Restriction requirement against amended claims 1-13, improperly issuing a restriction on the basis that the claims were related as a subcombination and combination; the Examiner refused to examine these claims on the merits. The Examiner maintained the remaining rejections with respect to claims 23 and 25-27.

Appellant’s representative held a telephonic interview with the Examiner pointing out the error in the restriction requirement, as well as discussing the rejections on the merits.

Appellants traversed the restriction and filed an amendment under 35 U.S.C. § 1.121 on April 3, 2009, with a clarifying amendments to claims 1, 23, and 28-29 and adding new claim 31. Appellants also submitted numerous exhibits discussing hydroentangling fabrics as evidence. On July 1, 2009 the Examiner then issued a Notice of Non Compliant Amendment on the status identifiers, to which Appellants filed a response on July 17, 2009.

On August 25, 2009, the Examiner issued a Final Office Action, rejecting claims finalizing the restriction of claims 1-13. Claims 23, 25-27 were again rejected under

35 U.S.C. §112, second paragraph Claims 23, 25-27 and 31 were rejected under 35 U.S.C. §102(b) or, in the alternative, over 35 U.S.C. §103 over Gaisser in view of WO 01/88261 to Strandqvist. Claims 23, 25-27, and 31 were also rejected under 35 U.S.C. § 103(a) over Greenway in view of U.S. Patent No. 4,345,730 to Leuvelink or Gassier. Claims 23, 25-27, and 31 were newly rejected under 35 U.S.C. § 103(a) over U.S. Patent No. 3,493,462 to Bunting (“Bunting”) in view of U.S. Patent No. 5,840,637 to Denton (“Denton”). Claims 23 and 25-27 and 31 were again rejected under 35 USC § 103(a) over Elsener in view of any one of Schwartz or Whight.

On November 24, 2009 Appellants’ representative held a telephonic interview with the Examiner on the Restriction requirement, proposing a clarifying amendment. The Examiner stated Petition would be required to resolve the improper restriction. On November 25, 2009, Appellants responded with an After Final Amendment with clarifying amendments to claim 1 and 23. Appellants also filed a Petition from the Requirement of Restriction.

On December 24, 2009 the Director of the Technology Center granted the Petition from Requirement for Restriction in the above-referenced case.

The Examiner then issued a Supplemental Final Office Action dated January 12, 2010; the Action was made Final despite the fact that the Examiner had never examined the petitioned claims on the merits. The Examiner withdrew the rejections of claims 23, 25-27, and 31 over Greenway in view of Leuvelink or Gaisser as well as those over Bunting in view of Denton. Claims 23, 25-27 and 31 were newly rejected under 35 U.S.C. §102(b) over Gaisser in view of WO 01/88261 to Strandqvist (“Strandqvist”). Claims 1-2, 4, 6-8, 13, 23, 25-27 and 31 are rejected under 35 U.S.C. §102(b) or, in the alternative, over 35 U.S.C. §103 over Strandqvist in view of Gaisser. Claims 1-2, 4, 6-8, 13, 23, 25-27, and 31 were also rejected under 35 U.S.C. § 103(a) over U.S. Patent No. 5,142,752 to Greenway in view of Gaisser. Finally, claims 23 and 25-27 and 31 are remained rejected under 35 USC § 103(a) over Elsener in view of any one of Schwartz or Whight.

On March 15, 2010, the Appellants filed a Response arguing the rejections; no claims were amended.

The Examiner issued an Advisory Action on March 22, 2010. In response, Appellants filed a Request for Continued Examination on April 12, 2010, along with a Request for Interview.

*The Fifth Round of Prosecution*

On April 19, 2010 Appellants representatives held a telephonic interview with the Examiner and Supervisory Examiner. On May 5, 2010, the Appellants filed a supplemental amendment incorporating the suggestions of the Examiners, including portions of the specification evidencing the unexpected results of the presently claimed invention and amendments directed thereto. The Amendment also included further evidence as to what ordinarily skilled artisans understand about hydroentangling.

The Examiner issued a non-final rejection on May 14, 2010. Claims 34 and 36 were rejected under 35 U.S.C. §112 first paragraph as allegedly lacking written description. Claims 1-2, 4, 6-8, 13, 23, 25-27, and 31-36 were rejected under 35 U.S.C. §112, second paragraph for allegedly being indefinite. Claims 1-2, 4, 6, 13, 23, 25-27, 31, and 33-36 are rejected under 35 U.S.C. §102 or §103 over International Pat. Pub. No. WO 01/25522 to Noelle (“Noelle”). Claims 23, 25-27, 31, 32 and 35-36 were again rejected under 35 U.S.C. §102 or §103 over Gassier. Claims 1-2, 4, 6, 13, 23, 25-27, 31, and 33-36 were rejected under 35 U.S.C. §102 or §103 over U.S. Pat. No. 6,074,966 to Zlatkus (“Zlatkus”). Claims 2-4, 6-8, 13 and 32-36 were rejected under 35 U.S.C. §103 over Noelle in view of Gassier. Claims 1-2, 4, 6, 13, 23, 25-27, 31, and 33-36 are rejected under 35 U.S.C. §103 over Gassier in view of Strandqvist. Claims 2-4, 6-8, 13 and 32-36 were rejected under 35 U.S.C. §103 over Zlatkus in view of Gassier. Claims 1-2, 4, 6, 13, 23, 25-27, 31, and 33-36 were rejected under 35 U.S.C. §103 over Strandqvist in view of U.S. Pat. No. 3,790,438 to Lewis (“Lewis”). Claims 1-2, 4, 6, 13, 23, 25-27, 31, and 33-36 were rejected under 35 U.S.C. § 103(a) over Greenway in view of either Noelle, Zlatkus, or U.S. Pat. No. 5,915,422 to Fagerholm (“Fagerholm”). Claims 2-4, 6-8, 13 and 32-36 were rejected under 35 U.S.C. §103 over Greenway in view of either Noelle, Zlatkus, of Fagerholm, and further in view of Gassier. Claims 23, 25-27 and 31 remained rejected under 35 USC § 103 (a) over Elsener in view of any one of Schwartz or Whight.

In response, Appellants filed an amendment under 35 U.S.C. § 1.121 on July 27, 2010 amending claims 33, 35 and 36 to address objections. The Appellants otherwise responded to the claims without substantive amendment.

The Examiner responded with a Final Office Action on August 5, 2010, repeating the rejections. On September 24, 2010, the Appellants filed a Response arguing the rejections; no amendments were made.

The Examiner issued an Advisory Action on September 29, 2010. In response, Appellants filed a Notice of Appeal on November 5, 2010 appealing the final rejection.

Accordingly, the status of the claims may be summarized as follows:

Claims Canceled:	14-22 and 30
Claims Allowed:	None
Claims Rejected:	1, 2, 4, 6-8, 13, 23, 25-27, 31-36
Claims Withdrawn:	3, 5, 9-12, 24, 28, 29
Claims Objected To:	None

Rejected claims 1, 2, 4, 6-8, 13, 23, 25-27, and 31-36 are set forth in the Appendix attached hereto. Appellants are appealing the Final rejections of claims 1, 2, 4, 6-8, 13, 23, 25-27, 31-36, which constitute all of the currently pending non-withdrawn claims in this application.

### **STATUS OF THE AMENDMENTS**

Appellants submit that no amendments have been filed subsequent to the final rejection. Accordingly Appellants believe that all the submitted Amendments have been entered.

### **SUMMARY OF THE CLAIMED SUBJECT MATTER**

The citation to Figures and Specification locations are provided immediately following elements of each of the claims which Appellants summarize below. However, such citations are merely examples and are not intended to limit the interpretation of the claims or to evidence or create any estoppel.

Claim 1 is directed to a hydroentangling apparatus for the production of a hydroentangled nonwoven product [Figure 3, page 5, line 31 to page 6, line 2, page 7, lines 19-27], the improvement comprising a hydroentangling support fabric having the mechanical properties and structural strength to reflect liquid jetted from the hydroentangling apparatus [Figure 3, ref 12, page 7, lines 19-27<sup>1</sup>] and comprising flat filaments [Figure 2, page 9, line 5 to page 10, line 1] wherein said support fabric is in a continuous loop or made endless [Figure 1, ref 12, page 7, lines 25-27].

Claim 23 is directed toward an improved hydroentangling support fabric in a hydroentangling apparatus for production of a hydroentangled nonwoven product [Figure 3, page 7, lines 19-27], the improvement comprising: said hydroentangling support fabric in the hydroentangling apparatus having the mechanical properties and structural strength to reflect liquid jetted from the hydroentangling apparatus [Figure 3, ref 12, page 7, lines 19-27<sup>2</sup>] and comprising flat filaments [Figure 2, page 9, line 5 to page 10, line 1], wherein said support fabric is in a continuous loop or made endless [Figure 1, ref 12, page 7, lines 25-27].

Claim 33 is directed toward the apparatus of claim 1 wherein said the flat filaments of the support fabric are incorporated into the structure of the fabric such that they include mechanical and structural properties, the mechanical and structural properties being selected from the group consisting of:

a weave thickness  $T'$  that is smaller than a thickness  $T$ , wherein  $T$  represents a thickness without said flat filaments [Fig. 2, Page 9, lines 10-21];

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<sup>1</sup> Referring to column 2, line 25 to column 4 line 3 of U.S. Patent No. 6,163,943.

<sup>2</sup> Referring to column 2, line 25 to column 4 line 3 of U.S. Patent No. 6,163,943.

a weave more resistant to water flow in a direction perpendicular or substantially perpendicular to the plane in which a plurality of CD monofilaments lie as compared to a fabric without said flat filaments [Fig. 2, Page 9, lines 21-28];

a structure that reduces entangling of fibers to the fabric surface as compared to a fabric without said flat filaments [Fig. 2, Page 9, lines 21-28];

improved MD/CD tensile ratios as compared to a fabric without said flat filaments [Page 14, lines 5-8, Figures 4A, 4B];

a structure that improves the fabric's reflection of water jets as compared to a fabric with non-flat filaments [Page 13 line 30 to page 14, line 6, Figures 4A, 4B, 8]; and

a structure that improves release of the fiber web from the hydroentangling fabric after entangling as compared to a fabric without said flat filaments [Page 14, lines 5-8, Figures 4A, 4B].

Claim 34 is directed toward the apparatus of claim 1, wherein the liquid is jetted from the hydroentangling apparatus at pressures from at least 200 psi [Figure 3, ref 16, page 7, lines 19-27<sup>3</sup>].

Claim 35 is directed toward the support fabric in the hydroentangling apparatus of claim 23 wherein said the flat filaments of the support fabric are incorporated into the structure of the fabric such that they include mechanical and structural properties, the mechanical and structural properties being selected from the group consisting of:

a weave thickness T' that is smaller than a thickness T, wherein T represents a thickness without said flat filaments [Fig. 2, Page 9, lines 10-21];

a weave more resistant to water flow in a direction perpendicular or substantially perpendicular to the plane in which a plurality of CD monofilaments lie as compared to a fabric without said flat filaments [Fig. 2, Page 9, lines 21-28];

a structure that reduces entangling of fibers to the fabric surface as compared to a fabric without said flat filaments [Fig. 2, Page 9, lines 21-28];

improved MD/CD tensile ratios as compared to a fabric without said flat filaments [Page 14, lines 5-8, Figures 4A, 4B];

a structure that improves the fabric's reflection of water jets as compared to a fabric with non-flat filaments [Page 13 line 30 to page 14, line 6, Figures 4A, 4B, 8]; and

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<sup>3</sup> Referring to column 2, line 25 to column 4 line 3 of U.S. Patent No. 6,163,943.

a structure that improves release of the fiber web from the hydroentangling fabric after entangling as compared to a fabric without said flat filaments [Page 14, lines 5-8, Figures 4A, 4B].

Claim 36 is directed toward the support fabric in the hydroentangling apparatus of claim 23, wherein the liquid is jetted from the hydroentangling apparatus at pressures of from at least 200 psi [Figure 3, ref 16, page 7, lines 19-27<sup>4</sup>].

*Hydroentangling Machines and Hydroentangling Support Fabrics*

The claims recite a hydroentangling apparatus in combination with: "...a hydroentangling support fabric having **the mechanical properties and structural strength to reflect liquid from the hydroentangling apparatus and comprising flat filaments, wherein said support fabric is in a continuous loop or made endless.**" Hydroentangling support fabrics when formed into a continuous belt (i.e., a continuous loop or made endless) must have very specific structures. As explained in Exhibit A<sup>5</sup>

Hydroentanglement is a mechanical bonding process designed to produce nonwoven fabrics with the texture and appearance that resemble woven and knitted fabrics. In a typical hydroentanglement process, a row or multiple rows of highly pressurized, fine, closely spaced water jets impinge on a fiberweb, which is supported by forming wires (*Figure 1*). Due to the impact of water jets, fibers are displaced and rotated around other fibers that surround them, resulting in fibers twisting and entangling around the neighboring fibers. The fabric produced is held together by the fiber-to-fiber

The Background of U.S. Patent 6,163,943 (the '943 patent')<sup>6</sup> explains: "Hydroentangling or spunlacing is a technique introduced during the 1970'ies [sic], see e.g., CA patent no. 841 938." CA 841,938 explains that hydroentangling apparatuses "jet[] water supplied at pressures of 200 to 2000 pounds per square inch (psi)." CA 841,938.<sup>7</sup> U.S. 4,967,456 further explains: "First and second stage enhancement is preferably effected by columnar

<sup>4</sup> Referring to column 2, line 25 to column 4 line 3 of U.S. Patent No. 6,163,943.

<sup>5</sup> *Fibers Caught in the Knuckles of the Forming Wires: Experimental Measurements and Physical Origins of the Force of Peeling in the Hydroentanglement Process*, Abdelfattah Mohamed Seyam, Ph.D. Ping Xiang; Andrey V. Kuznetsov, Ph.D., page 1

<sup>6</sup> See column 2 lines 25 to column 4, line 3 of U.S. Patent 6,163,943 (the '943 patent'), incorporated by reference at paragraph 12 of the published application, which in turn refers to CA patent no 841,938 (see '943 patent at col. 3, lines 54-56).

<sup>7</sup> *Id.*

fluid jets which impact the fabric at pressures within the range of 200 to 3000 psi and impart a total energy to the fabric of approximately 0.10 to 2.0 hp-hr/lb.<sup>8</sup>) Such properties are well known to ordinarily skilled artisans. Exhibits A-C discuss, in general, the type of fabrics used in a hydroentangling process. As examples, Figures 5-8 of Exhibit A show magnified photographs of 10 – 100 mesh forming belts at 50 g/m<sup>2</sup> and 100 g/m<sup>2</sup> webs and Figures 2a to 2c of Exhibit B showing spunlace support wire.

As the claims recite a hydroentangling apparatus in combination with the hydroentangling support fabric in a continuous loop or made endless, at the suggestion of the Examiner and Supervisory Appellants cited evidence as to the advantages of the claimed flat filaments in hydroentangling support fabrics. Indeed, **none of the evidence herein in the present Appeal Brief is new; all has been presented during prosecution in support of the remarks herein.**

For evidentiary support of the unexpected advantages of the claimed flat filaments in hydroentangling support fabrics, Appellants quote the specification, which states:

In any event, the support fabrics of the invention include flattened monofilaments. The flattened monofilaments may be all or some of the CD monofilaments, all or some of the MD monofilaments, or some combination of CD and MD monofilaments. Figures 1 and 2 serve as a comparison of a single layer weave without flattened monofilaments to a single layer weave with flattened monofilaments. As can be seen, Figure 1 shows a round MD monofilament 2 and several round CD monofilaments 4. Figure 2 shows a single round MD monofilament 6 and several flattened CD monofilaments 8. Thus, the embodiment depicted in Figure 2 is an embodiment in which all of the CD monofilaments are flattened. The use of the flattened CD monofilaments gives the weave of Figure 2 a thickness T' that is smaller than the thickness T of the Figure 1 weave. Furthermore, the use of the flattened monofilaments makes the weave of Figure 2 more resistant to water flow in a direction perpendicular or substantially perpendicular to the plane in which the CD monofilaments lie. Shaded areas A and A' are provided merely for purposes of facilitating visual comparison.

Page 9, lines 10-28, and

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<sup>8</sup> See also U.S. Patent 5,136,761 at col. 3, lines 58-62 (previously identified as Exhibit C).

The fabrics of the invention may be formed as single, double or triple layer weaves. Flattened monofilaments may be incorporated into any one layer or into any combination of layers, and in any configuration within a given layer... .[T]he fibers of the nonwoven are supported by the round monofilaments of the forming side while the flat monofilaments promote greater reflective water flow, and therefore greater reflective entanglement energy. By promoting greater reflective entanglement energy, the fabric promotes greater entanglement of the fibers making up the nonwoven, and thereby provides for a stronger finished nonwoven. That is, when water is directed at the fabric in a direction perpendicular, or substantially perpendicular to the plane in which the flattened yarns lie, some water will pass through the forming surface layer and intermediate layer, reflect off the wearside layer, and further entangle the fibers....

As in the triple layer embodiment, the fibers of the nonwoven are supported by the round monofilaments of the forming side while the flat monofilaments promote greater reflective water flow, and therefore greater reflective entanglement energy.

Page 9, line 30 to page 10 line 7. And:

The advantages of hydroentangling according to the invention are confirmed using modified versions of the fabric of Figures 4A and 4B on a machine incorporating the structure of Figure 8. In particular, the invention reduces entangling of fibers to the fabric surface and improves reflection (or “flashback”) of water jets. Furthermore, the invention improves release of the fiber web from the hydroentangling fabric after entangling and improves MD/CD tensile ratios. More specifically, tests using a machine in accordance with Figure 8 have shown that release of the fiber web from the hydroentangling fabric improves such that the draw is reduced from about 8% to 0%, and that the MD/CD ratio improvement is about 10% to 40%.

Page 13 line 30 to page 14, line 12. As requested by the Examiners, the specification evidences the many advantages of flat filaments in hydroentangling support fabrics over that of hydroentangling support fabrics, including but not limited to:

- a weave thickness T' that is smaller than the thickness T, wherein T represents a thickness without said flat filaments;

- a weave of more resistant to water flow in a direction perpendicular or substantially perpendicular to the plane in which a plurality of CD monofilaments lie;
- structure that reduces entangling of fibers to the fabric surface;
- improved MD/CD tensile ratios as compared to a fabric without said flat filaments; and
- improved release of the fiber web from the hydroentangling fabric after entangling.

Therefore, the support fabric of the claimed invention is in a continuous loop or made endless that includes flat filaments. As combined into a hydroentangling device for the production of a hydroentangled nonwoven product, the flat monofilaments, inter alia, promote greater reflective water flow, and therefore greater reflective entanglement energy. By promoting greater reflective entanglement energy, the fabric promotes greater entanglement of the fibers making up the nonwoven, and thereby provides for a stronger finished nonwoven.

#### **GROUND FOR REJECTION TO BE REVIEWED ON APPEAL**

Whether claims 34 and 36 are patentable under the 35 U.S.C. §112 first paragraph written description requirement.

Whether claims 1-2, 4, 6-8, 13, 23, 25-27, and 31-36 are patentable under 35 U.S.C. §112, second paragraph as definite.

Whether claims 33 and 35 are patentable under 35 U.S.C. §112, second paragraph as definite.

Whether claims 1-2, 4, 6, 13, 23, 25-27, 31, and 33-36 are patentable over International Pat. Pub. No. WO 01/25522 to Noelle (“Noelle”) under 35 U.S.C. §102 (b) or §103(a).

Whether claims 1-2, 4, 6, 13, 23, 25-27, 31, and 33-36 are patentable over U.S. Patent No. to Gassier (“Gassier”) under 35 U.S.C. §102 (b) or §103

Whether claims 1-2, 4, 6, 13, 23, 25-27, 31, and 33-36 are patentable over U.S. Patent No. 6,074,966 to Zlatkus (“Zlatkus”) under 35 U.S.C. §102 (b) or §103(a).

Whether claims 2-4, 6-8, 13 and 32-36 are patentable over Noelle in view of Gassier under 35 U.S.C. §103(a).

Whether claims 1-2, 4, 6, 13, 23, 25-27, 31, and 33-36 are patentable and non-obvious over Gassier in view of International Pat. Pub. No. WO 01/88261 Strandqvist (Strandqvist”) under 35 U.S.C. § 103(a).

Whether claims 2-4, 6-8, 13 and 32-36 are patentable over Zlatkus in view of Gassier under 35 U.S.C. § 103(a).

Whether claims 1-2, 4, 6, 13, 23, 25-27, 31, and 33-36 are patentable over Strandqvist in view of U.S. Pat. No. 3,790,438 to Lewis (“Lewis”) under 35 U.S.C. §103(a).

Whether claims 1-2, 4, 6, 13, 23, 25-27, 31, and 33-36 are patentable over Greenway in view of either Noelle, Zlatkus, or U.S. Pat. No. 5,915,422 to Fagerholm (“Fagerholm”) under 35 U.S.C. §103(a).

Whether claims 2-4, 6-8, 13 and 32-36 are patentable over Greenway in view of either Noelle, Zlatkus, of Fagerholm, and further in view of Gassier under 35 U.S.C. §103(a).

Whether claims 23, 25-27 and 31 are patentable over U.S. Patent No. 5,883,022 to Elsener (“Elsener”) in view of U.S. Patent No. 3,884,630 to Schwartz (“Schwartz”) or U.S. Patent No. 4,104,814 to Whight (“Whight”) under 35 U.S.C. §103(a).

For the sake of more straightforward presentation of the issues, the rejections are taken in different order than presented by the Examiner, and certain of the dependent claims are addressed under the heading of each rejection.

## ARGUMENTS

### **I. CLAIMS 34 AND 36 ARE PATENTABLE UNDER 35 U.S.C. § 112, FIRST PARAGRAPH**

Claims 34 and 36 are rejected under 35 U.S.C. §112 first paragraph as allegedly lacking written description. Claims 34 and 36 each recite: “the liquid is jetted from the hydroentangling apparatus at pressures from at least 200 psi.” At page 3 of the Final Office Action the Examiner alleges that the recitation of “200 psi” lacks written description support. As was discussed during the prior interview, and explained in the prior response: column 2 line 25 to column 4, line 3 of U.S. Patent 6,163,943 (the ‘943 patent’) is incorporated by reference at paragraph 12 of the published application. The ‘943 patent in turn refers to CA patent no 841,938 (see ‘943 patent at col. 3, lines 54-56). Appellants also submitted as evidence U.S. Patent No. 4,967,456, of record in the present application. **The evidence shows that hydroentangling apparatuses “jetting water supplied at pressures of 200 to 2000 pounds per square inch (psi).” CA 841,938. (See also US 4,967,456: “First and second stage enhancement is preferably effected by columnar fluid jets which impact the fabric at pressures within the range of 200 to 3000 psi and impart a total energy to the fabric of approximately 0.10 to 2.0 hp-hr/lb.”)**

Appellants also noted that that as such properties are well known, stating:

As explained in the Background of ‘943 Patent “Hydroentangling or spunlacing is a technique introduced during the 1970’ies [sic], see e g CA patent no. 841 938.” Hence there is ample support for the amendments with respect to such properties with or without incorporating the above-noted documents by reference into the present specification. ( See *Falkner v. Inglis*, 79 USPQ2d 1001 (Fed. Cir. 2006), showing the recitation of known structure is not required under 112, and indeed, such recitation is disfavored: ‘Indeed, the forced recitation of known sequences in patent disclosures would only add unnecessary bulk to the specification. Accordingly we hold that where, as in this case, accessible literature sources clearly provided, as of the relevant date, [claimed structure], satisfaction of the written description requirement does not require either the recitation or incorporation by reference.’)

In response, the Examiner's admits the above-incorporated patents' disclosure, but responds, "Applicant's argument is not persuasive because although it may have been known option to use the claimed pressure of at least 200 psi, there is no evidence that the liquid jetted from the claimed invention was at a pressure of at least 200 psi." Final Office Action, page 23. The above-recited language describes the well-known operation of hydroentangling machines. Hydroentangling apparatuses jet water at pressures within the range of 200 to 3000 psi, the incorporated references expressly refer to this, and Appellants have more than proved that this is common knowledge to the ordinarily skilled artisan. Thus the assertion that there is no written description support for such a recitation is clear error, and represents a fundamental misapplication of the law of written description to facts of the present case.

**II. CLAIMS 1-2, 4, 6-8, 13, 23, 25-27, AND 31-36 PATENTABLE UNDER  
35 U.S.C. §112, SECOND PARAGRAPH AS THE CLAIMS ARE NOT INDEFINITE**

**A. Independent claims 1 and 23 recite structural properties of  
hydroentangling fabrics, which are clear to Ordinarily Skilled Artisans**

Claims 1-2, 4, 6-8, 13, 23, 25-27, and 31-36 are rejected under 35 U.S.C. §112, second paragraph for allegedly being indefinite. Independent claims 1 and 23 each recite: "**a hydroentangling support fabric having the mechanical properties and structural strength to reflect liquid jetted from the hydroentangling apparatus.**"

At page 3 of the Final Office Action, the Examiner alleges the recitation is indefinite, citing as an example variables of time and pressure. Ordinarily skilled artisans are well aware of the mechanical properties and structural strength required for reflecting liquid jetted from a hydroentangling apparatus, and the claims cover this. **Again, the evidence shows that hydroentangling apparatuses "jetting water supplied at pressures of 200 to 2000 pounds per square inch (psi)." CA 841,938. (See also US 4,967,456: "First and second stage enhancement is preferably effected by columnar fluid jets which impact the fabric at pressures within the range of 200 to 3000 psi and impart a total energy to the fabric of approximately 0.10 to 2.0 hp-hr/lb.").** Appellants are not claiming a particular combination of variables, nor is this required by law.

Appellants also note that in the spirit of advancing prosecution, Appellants added new claims 34 and 36, discussed above, which positively recite that the water from a hydroentangling apparatus is at a pressure of at least about 200psi. Thus these claims expressly recite the features thus rejected. Rejection of such a recitation as indefinite is in error.

The Examiner's response to these arguments at page 23 of the Final Office Action is: "Applicant's argument is not persuasive because although it may have been known to use a specific total energy and a specific time, said features are not recited in the rejected claims." The Examiner's position appears to be that unless a specific total energy and time is recited in the claim, the claim is indefinite. This is in error. The rejection is predicated on the belief, despite all the evidence provided above and throughout prosecution to the contrary, that an ordinarily skilled artisan would find indefinite or ambiguous a recitation that expressly recites a structural requirement of all hydroentangling fabrics -- namely that they reflect liquid jetted from a hydroentangling apparatus. The argument requires that an ordinarily skilled artisan not understand what a hydroentangling fabric is, which is absurd. Indeed, it is noted that the recitations were only added as a concession to the Examiner to clarify the inherent mechanical properties that are clear to ordinarily skilled artisans. Further recitations of the known and well understood attributes of hydroentangling fabrics and apparatuses would only clutter the claim with more unnecessary verbiage.

Accordingly, Appellants respectfully submit that the claims are presently in condition for allowance and urge reconsideration and reversal of the Examiner's rejection.

#### **B. Claims 33 and 35 Recite a Proper Markush Format**

The Examiner rejects claims 33 and 35 for being in a Markush format, citing the reference to properties where the flat filament is not present. Exemplary claim 35 recites:

35. (Previously Presented) The support fabric in the hydroentangling apparatus of claim 23 wherein said the flat filaments of the support fabric are incorporated into the structure of the fabric such that they include mechanical and structural properties, the mechanical and structural properties being selected from the group consisting of:

a weave thickness  $T'$  that is smaller than a thickness  $T$ , wherein  $T$  represents a thickness without said flat filaments;

a weave more resistant to water flow in a direction perpendicular or substantially perpendicular to the plane in which a plurality of CD monofilaments lie as compared to a fabric without said flat filaments;

a structure that reduces entangling of fibers to the fabric surface as compared to a fabric without said flat filaments;

improved MD/CD tensile ratios as compared to a fabric without said flat filaments;

a structure that improves the fabric's reflection of water jets as compared to a fabric with non-flat filaments;  
and

a structure that improves release of the fiber web from the hydroentangling fabric after entangling as compared to a fabric without said flat filaments.

The Examiner alleges: “[I]t is not clear if all the other variables are the same between the two scenarios. For example, materials, structure, element size, and or/density.” Page 24 of the Final Office Action. The claims clearly recite a number of mechanical and structural properties, all of which described in the specification, and each of which expressly claim the unexpected advantages and superior properties of the **claimed flat filaments in hydroentangling support fabrics**. See pages 5-6 and page 8, second full paragraph of the present Specification, referred to in the Summary. Appellants urge they are amply clear to an ordinarily skilled artisan, and the Examiner's reference to “other variables” are not required, nor even germane to, the definiteness requirement of 112. Indeed, each member of the group clearly articulates an improved feature that is directly attributable to the structure of a flat filament replacing a non-flat one, regardless of all the other variables.

Accordingly, Appellants respectfully submit that the claims are presently in condition for allowance and urge reconsideration and reversal of the Examiner's rejection.

**III. THE CLAIMS ARE PATENTABLE UNDER 35 U.S.C. §103 OVER ELSENER IN  
VIEW OF ANY ONE OF SCHWARTZ OR WHIGHT**

Claims 23, 25-27 and 31 were rejected under 35 USC § 103 (a) over Elsener in view of any one of Schwartz, or Whight. Appellants traverse and request reconsideration and reversal of the rejections.

As the Examiner acknowledges, Elsener is a textile fabric for use in clinical areas or clean rooms, namely a towel is for drying hands and skin. Specifically, Elsener discloses an absorbent fabric material of synthetic endless fibers, in particular for use in clinical areas and also clean room areas and also in company and public washrooms (Elsener -- Abstract). Therefore, Elsener has absolutely nothing to do with endless or continuous industrial process fabrics whatsoever.

Schwartz relates to a towel apparatus which handles an endless towel within a cabinet and subjects the same to cleaning and drying making use of a low vapor pressure chemical type solvent. (Schwartz -- Abstract). Whight relates to a clean towel presenting machine, which includes an endless web of liquid absorbent material contained in a casing to discontinuously present a clean portion and simultaneously retract an essentially equal used portion through an intake slot, a cleaning liquid tank and a heater to dry and sterilize the web. (Whight -- Abstract).

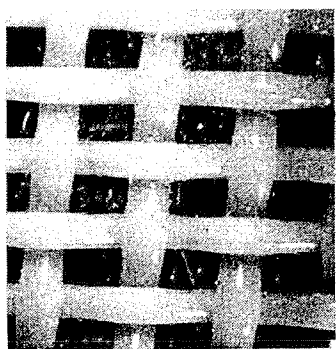
In view of the extensive discussions of hydroentangling fabrics above and in prior responses, it almost goes without saying that an ordinarily skilled artisan would not look to hand towels for teachings on industrial process belts. The cited art is in no way analogous to hydroentangling fabrics.

It is well established that non-analogous art cannot be considered pertinent prior art under §103 and therefore cannot be relied upon as a "'basis for rejection of an applicant's invention'." See M.P.E.P. § 2141.01(a) (quoting *In re Oetiker*, 977 F.2d 1443, 1446 (Fed. Cir. 1992)). The determination as to whether a reference is analogous art is two fold. First, it must be decided if the reference is within the field of the inventor's endeavor. If it is not, it must then be determined whether the reference is "reasonably pertinent to the particular problem with which the inventor was concerned." *In re Oetiker*, 977 F.2d at 1446. The Federal Circuit has held: "A reference is reasonably pertinent if, even though it may be

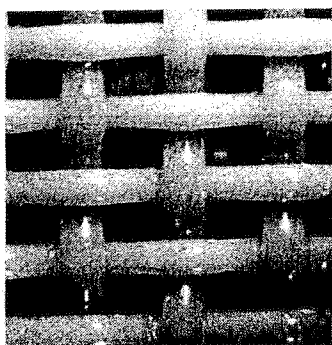
in a different field from that of the inventor's endeavor, it is one which, because of the matter with which it deals, logically would have commended itself to an inventor's attention in considering his problem." In re Clay, 966 F.2d 656, 659 (Fed. Cir. 1992).

In the present case, the Elsener, Schwartz, and Whight references do not satisfy the above well-established test of a reference falling into the category of analogous art. Moreover, it is clear that the matters with which Elsener, Schwartz, and Whight deal would not logically have commended themselves to the instant inventors' attention in considering any problem to be solved for hydroentangling fabrics, much less those that the present inventor's were focused on. As such, this rejection should be reversed as well.

Moreover, Appellants have repeatedly referred to Exhibits A-C, submitted in the Amendment and Response dated April 3, 2009, which discuss, in general, the type of fabrics used in a hydroentangling process. Appellants referred in particular to, for example the photographs of Figures 5-8 of Exhibit A (showing magnified photographs of 10 – 100 mesh forming belts at 50 g/m<sup>2</sup> and 100 g/m<sup>2</sup> webs), reproduced below:



(a) 50 g/m<sup>2</sup> web



(b) 100 g/m<sup>2</sup> web

FIGURE 5. Magnified photographs of 10 mesh forming belts after fabric has been removed from them (final jet pressure: 200 bar, magnification: 0.8)

Appellants also referred to Figures 2a to 2c of Exhibit B (showing spunlace support wire, and products made thereon).

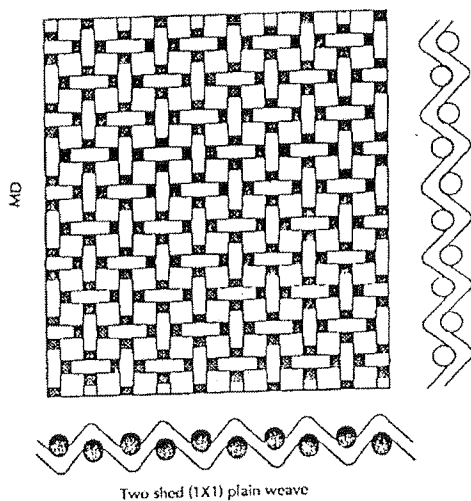


Fig. 2a: Spunlace support wire details

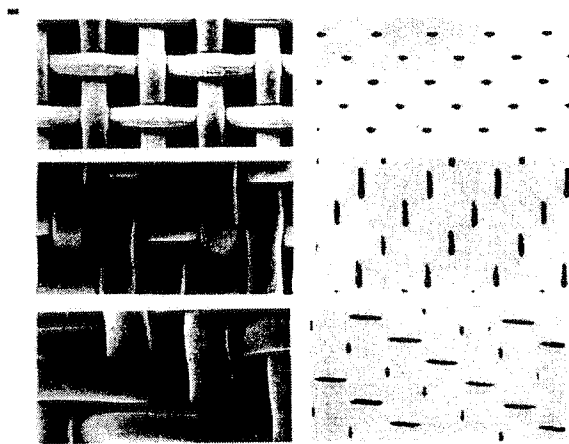


Fig. 2b: Spunlace support wire and the product

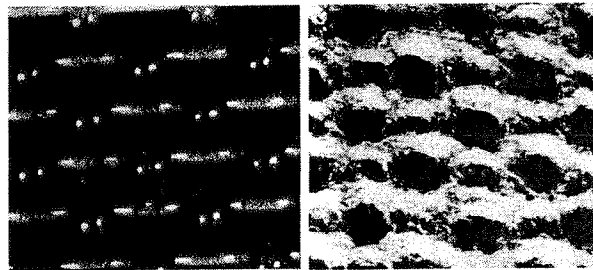


Fig. 2c: Spunlace support wire and the product enlarged

The Exhibits show that Elsener's, Schwartz's, and Whight's hand drying towels are not hydroentangling support fabrics and such towels could in no way be used a hydroentangling fabric. The Examiner never once commented on these Exhibits. Indeed, after the evidence was first presented, the Examiner merely stated in the subsequent response (not mentioning the evidence itself): "Applicant's argument is not persuasive because one skilled in the art of industrial process belts is not required for said rejection. Rather, only one skilled in the art of hand towels is required." Final Rejection of August 25, 2009, page 10.

Appellants also amended the claims to recite that the fabric includes "the mechanical properties and structural strength to reflect liquid from the hydroentangling apparatus." As proof as to what an ordinarily skilled artisan would understand about such mechanical properties and structural strength, Appellants again refer to column 2 lines 25 to column 4, line 3 of U.S. Patent 6,163,943 (the '943 patent"), incorporated by reference at paragraph 12 of the published application. The '943 patent turn refers to CA patent no 841,938 (see '943 patent at col. 3, lines 54-56). Appellants also submitted U.S. 4,967,456.

The evidence shows that hydroentangling apparatuses “jetting water supplied at pressures of 200 to 2000 pounds per square inch (psi).” CA 841,938. (See also US 4,967,456: “First and second stage enhancement is preferably effected by columnar fluid jets which impact the fabric at pressures within the range of 200 to 3000 psi and impart a total energy to the fabric of approximately 0.10 to 2.0 hp-hr/lb.”) Hand towels and the like cannot stand up to such pressures.

The Examiner has ignored all this evidence, save at page 23 of the Final Office Action, where the Examiner proffers that Appellants have failed to provide evidence that a hand towel cannot reflect columnar fluid jets which impact the fabric at pressures within the range of 200 to 2000/3000 psi and impart a total energy to the fabric of approximately 0.10 to 2.0 hp-hr/lb, while at the same time maintaining that any attempt to incorporate such features into the claims would render them indefinite. Appellants have already shown in detail that these properties are well-known structural properties of hydroentangling fabrics, and that the specification incorporates the references showing this into its disclosure – although this is not necessary for support. It is unreasonable to require that Appellants prove that utterly non-analogous art – hand towels – renders any aspect of a hydrogenating fabric for a hydroentangling apparatus obvious, especially when the Examiner has given no reason for such an assertion except that hand-towels are “substantially identical,” or that “it is within the general skill of a worker in the art [of hand towels, presumably] to select a known shape on the basis of its suitability and desired characteristics.” See pages 21-22 of the Office Action.

In short, Appellants have provided a raft of evidence which the Examiner has simply ignored. Moreover, the Examiner has also failed to address the arguments showing that the references are directed to non-analogous art, which is plain. The Examiner’s rebuttal is to rely on his 112 rejections, which is improper in an art rejection, and to allege “applicant fails to provide sufficient evidence that the fabric cannot withstand the claimed pressure.” With all due respect to the Examiner, it is absurd to base the rejection of a claim that unambiguously recites an industrial belt on the premise that a hand towel can be used as a support fabric for an industrial machine. In view of the fact that the Examiner has outright refused to consider or comment on the ample evidence Appellants have provided in a more than reasonable attempt to address this extremely non-analogous and irrelevant art,

Appellants regard it as unfair to provide still more absent the lack of consideration of that which Appellants have already submitted.

As nothing in the art of record cures the deficiencies as against the independent claims, Appellants urge these claims are in condition for allowance, and respectfully request that this Honorable Board reverse these rejections and mandate allowance of the claims.

#### IV. THE CLAIMS ARE PATENTABLE UNDER 35 U.S.C. §112 OVER NOELLE

Claims 1-2, 4, 6, 13, 23, 25-27, 31, and 33-36 are rejected under §102 or §103 over Noelle.

##### *Independent Claims 1 and 23*

The independent claims 1 and 23 recite: “a hydroentangling support fabric having the mechanical properties and structural strength to reflect liquid jetted from the hydroentangling apparatus and comprising flat filaments, wherein said support fabric is in a continuous loop or made endless.”

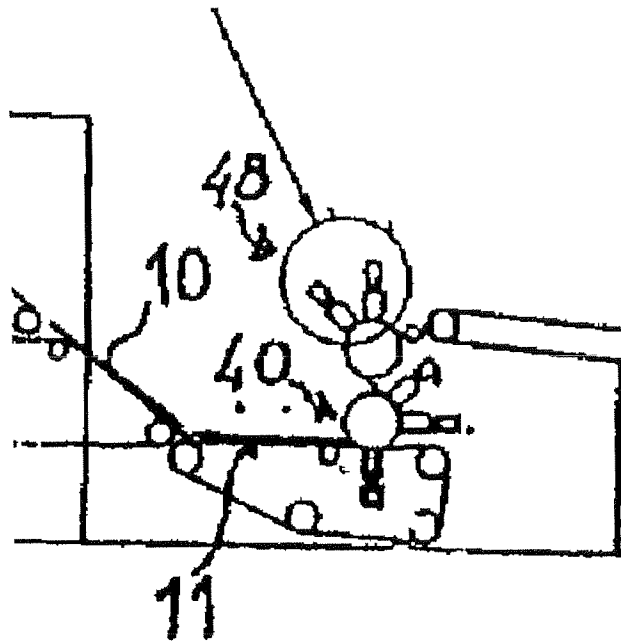
The Examiner cites Figure 2, paragraph [0092] of Noelle against the above-cited recitation. The cited section, however, shows the fabric is not a support fabric. Noelle states:

[0091] The web thus compacted and wetted is subjected to the action of two hydraulic injectors projecting water jets with a diameter of 120 microns at increasing velocities of 78 and 94 m/s, the water jets being spaced 1.2 mm from one another.

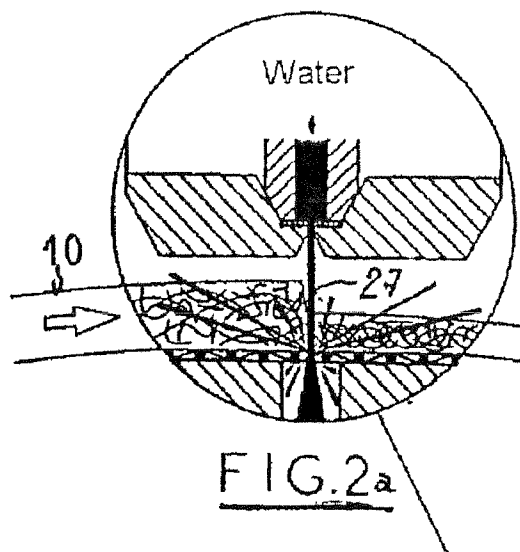
[0092] The web is then introduced to the assembly designated by the general reference ( 48 ), which comprises a **second cylinder covered with a coarse cloth** consisting of 9 wires per centimeter, made of bronze, with a rectangular cross section with sides of 0.3 mm by 6.64 mm in the warp direction and of 9 wires per centimeter, likewise made of bronze, with a diameter of 0.46 mm in the weft direction.

[0093] Two hydraulic injectors are arranged above this **cylinder**. They project onto the web water jets with a diameter of 120 microns at velocities of 100 m/s, the jets being spaced 0.5 mm from one another.

Emphasis added. The Figure shows the “second cylinder 48” as follows:



And in close up as follows:



As the figures show, the fabric is not a **support fabric** in a continuous loop or made endless, which an ordinarily skilled artisan would understand to be fabric or a belt. Rather it is a cloth covering for a cylinder. It is the drum that is supporting the non-woven web (see also claim 1 of Noelle: “producing a fibrous web...subjecting the moistened and compressed web to a bonding treatment by means of water jets acting at least against one of its faces, **the web being supported by a rotary drum...**”) Emphasis added.

As an example of what an ordinarily skilled artisan would understand as a **support fabric** for a hydroentangling apparatus, Figure 3 item 12 of the present application shows that the support fabric itself supports the web:

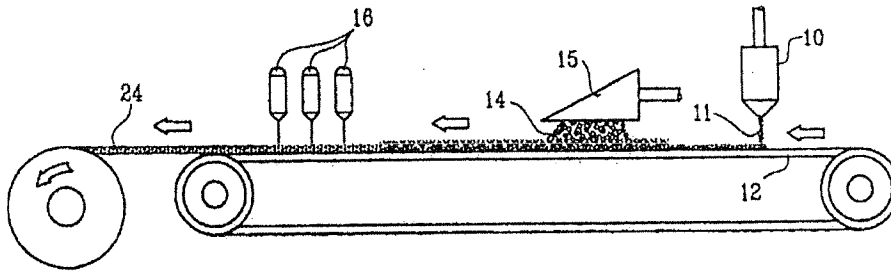


FIG. 3

And as explained in paragraph [0026] of the publication present application: “The hydroentangling support fabrics of the present invention may be applied in a hydroentangling system such as that shown in FIG. 3, which is described in detail in U.S. Pat. No. 6,163,943 as FIG. 1, at column 2, line 25 to column 4, line 3. When employed in a system such as that shown in FIG. 3, **the fabric of the invention would be formed into a continuous belt** and the belt would take the place of wire 12.” Emphasis added.

Thus an ordinarily skilled artisan would not regard a hydroentangling support fabric to be Noelle’s fabric sleeve covering for a cylinder, even under the broadest reading of that term, as Noelle’s fabric serves no support function. As Appellants explained in detail during prosecution, an ordinarily skilled artisan would understand that “when employed in a system such as that shown in FIG. 3, the fabric of the invention would be formed into a continuous belt and the belt would take the place of wire 12.” See paragraph [0026] of the present application. Thus an ordinarily skilled artisan would not regard a hydroentangling support fabric to be Noelle’s fabric covering for a cylinder, even under the broadest reading of that term, as Noelle’s fabric serves no support function.

The Examiner responds by stating (1) this attempts to import limitations of the specification into the claim and (2) the recitation is an intended use because Noelle’s fabric is inherently able to be used as the claimed fabric. Both statements are in error.

With respect to the first point, the independent claims recite a “hydroentangling support fabric... **wherein said support fabric is in a continuous loop**

**or made endless.**” The Federal Circuit's en banc decision in *Phillips v. AWH Corp.*, 415 F.3d 1303, 75 USPQ2d 1321 (Fed. Cir. 2005) expressly recognized that the USPTO employs the ‘broadest reasonable interpretation’ standard.... The broadest reasonable interpretation of the claims must also be consistent with the interpretation that those skilled in the art would reach. *In re Cortright*, 165 F.3d 1353, 1359, 49 USPQ2d 1464, 1468 (Fed. Cir. 1999).” MPEP §2111. The broadest reasonable construction rubric standard “...does not give the PTO an unfettered license to interpret claims to embrace anything remotely related to the claimed invention. Rather, claims should always be read in light of the specification and teachings in the underlying patent.” *In re Suitco Surface* (CAFC 2009-1418) (Decided April 14, 2010). The specification shows that an ordinarily skilled artisan would simply not read “a hydroentangling support fabric... wherein said support fabric is in a continuous loop or made endless” to cover a covering for a cylinder. Indeed, the term “hydroentangling support fabric” is understood to be a belt.

As an ordinarily skilled artisan would appreciate, a cloth drum cover is not a hydroentangling support fabric for a hydroentangling apparatus. Indeed, this is the teaching of Noelle itself. At paragraphs [0053]-[0055], Noelle states:

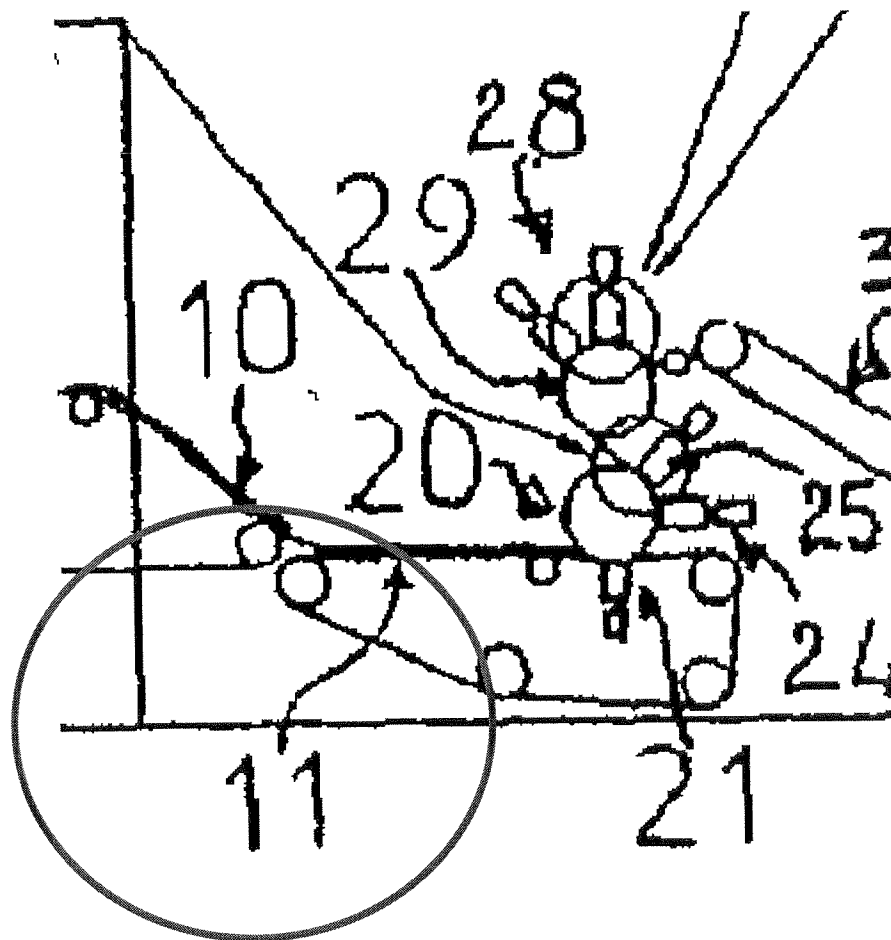
[0053] At the exit of the zone for shaping the web (10), the latter is transferred onto a **porous conveyer belt (11)** consisting, for example, of an endless cloth which is produced from synthetic monofilament, in particular from polyester, and which has a porosity of between 30 and 60%, that is to say a ratio between the solid areas and the empty areas of between 30 and 60%, preferably around 50%.

[0054] **This porous support (11)** is associated, in a way similar to the teachings of FR-A-2 730 246, with an assembly for treatment by water jets, making it possible, on the one hand, to ensure the compression and wetting of the web (10) formed and, on the other hand, to subject this web to the action of racks of water jets. Such an assembly comprises essentially a rotary cylindrical drum designated by the general reference (20), in bearing contact against the surface of the conveyer belt (11).

[0055] A first rack of water jets (21) is arranged below **the support (11)** and makes it possible to carry out the prewetting of the web (10). This rack is arranged at a distance of between 70 and 100 mm from the porous support (11) and forms a water curtain making it possible

to wet the compressed web and bringing about a first slight intermingling of the web.

Support (11) is shown at annotated Figure 1 as follows:



As Noelle itself proves, ordinarily skilled artisans distinguish a support fabric, which takes the form of a belt, from a covering for a drum. As such, and ordinarily skilled artisan would not interpret the term “hydroentangling support fabric,” to include a covering for a drum, even adopting the broadest reasonable construction of that term uninformed by the specification, much less when read in light of the specification.

As for the second point, it is also off base as the term “hydroentangling support fabric” is a specific kind of fabric, and hence represents structure, as has been shown throughout this prosecution and paper. This situation is analogous to that in *Corning Glass Works v. Sumitomo Electric*, 9 U.S.P.Q.2d 1962, 1966 (Fed. Cir. 1989). In that case the

court held that the use of the term "optical waveguide" did not merely state a purpose or intended use. Rather, it gave "life and meaning" to the claim and provided a further positive limitation to the invention claimed. The court, in making its determination, looked to the entire patent to determine and gain an understanding as to what the inventors actually invented and intended to encompass by the claim. The court noted that "[t]o read the claim in light of the specification indiscriminately to cover all types of optical fibers would be divorced from reality."

Here, as has been amply shown throughout prosecution, hydroentangling support fabrics are very specific fabrics. The claim requires a hydroentangling support fabric, which ultimately forms a belt. This is not an "intended use;" this is what it is. To interpret the term "hydroentangling support fabric" to embrace a cloth covered rotary drum is divorced from reality, and actively ignores all the evidence of record showing such differences.

Also the Examiner's charge that a cloth on a rotary drum is "inherently" capable of being used as a hydroentangling fabric has no basis. The Examiner bases this on the fact that fabric withstands liquid jetted from a hydroentangling apparatus. However Noelle states:

[0092] The web is then introduced to the assembly designated by the general reference ( 48 ), which comprises **a second cylinder covered with a coarse cloth** consisting of 9 wires per centimeter, made of bronze, with a rectangular cross section with sides of 0.3 mm by 6.64 mm in the warp direction and of 9 wires per centimeter, likewise made of bronze, with a diameter of 0.46 mm in the weft direction.

[0093] Two hydraulic injectors are arranged above this cylinder. They project onto the web water jets with a diameter of 120 microns at velocities of 100 m/s, the jets being spaced 0.5 mm from one another.

Thus the Office Action's reliance on inherency is misplaced. As explained at MPEP 2112:

To establish inherency, the extrinsic evidence 'must make clear that the missing descriptive matter is **necessarily present** in the thing described in the reference, and that it would be so recognized by persons of ordinary skill. **Inherency, however, may not be established by probabilities or possibilities. The mere fact that a certain thing may result from a given set of**

**circumstances is not sufficient.** *In re Robertson*, 169 F.3d 743, 745, 49 USPQ2d 1949, 1950-51 (Fed. Cir. 1999) (internal quotations omitted). Emphasis added.

As the drum supports the woven web, it cannot be said that it is inherent that the cloth placed thereon, as opposed to the drum, that allows the wires to withstand the jets. Moreover, there is simply no basis for asserting that the cloth could or should be pulled off the rotary drum and made to act as a hydroentangling support fabric.

Moreover Noelle describes its cloth covered drum and “additional” treatment, for the purpose of creating design textures. At paragraph [0034], it states:

[0034] The **additional treatment** by means of jets which is carried out before the drying of the web is obtained, as mentioned above, **by causing it to pass onto the surface of a perforated rotary cylindrical suction drum.** In a known way, such a drum consists of a honeycomb structure which is covered with a perforated plate and which rotates about a second hollow fixed coaxial cylindrical drum connected to a partial vacuum source in order to form a suction box below the zones where the water jets act. According to the invention, said drum is covered with a likewise perforated or intrinsically porous structure having raised and recessed zones, this structure preferably consisting of a woven fabric **taking the form of a removable sleeve.**

[0035] By virtue of such a design, it is therefore easy, simply by changing this sleeve, to modify the appearance and characteristics of the product obtained.

Thus the design of the **sleeve** for the rotary drum is not to act as a support belt for hydroentangling *per se*, but as a **removable sleeve a perforated rotary cylindrical suction drum in an additional step for embossing the web.** An ordinarily skilled artisan would have no reason to import the wire structures of a roll cover into the support fabric, and indeed, Noelle itself shows hydroentangling support fabrics yet in no way indicates that any element of the roll cover, much less the specific wire, should be incorporated into any support fabric. To the contrary, it adds an entirely new step to conventional hydroentangling to achieve its embossing, not reconfiguring a hydroentangling support fabric.

*Dependent claims 33 and 35*

Claims 33 and 35 recite:

The [apparatus of claim 1 /support fabric in the hydroentangling apparatus of claim 23] wherein said the flat filaments of the support fabric are incorporated into the structure of the fabric such that they include mechanical and structural properties, the mechanical and structural properties being selected from the group consisting of:

a weave thickness  $T'$  that is smaller than a thickness  $T$ , wherein  $T$  represents a thickness without said flat filaments;

a weave more resistant to water flow in a direction perpendicular or substantially perpendicular to the plane in which a plurality of CD monofilaments lie as compared to a fabric without said flat filaments;

a structure that reduces entangling of fibers to the fabric surface as compared to a fabric without said flat filaments;

improved MD/CD tensile ratios as compared to a fabric without said flat filaments;

a structure that improves the fabric's reflection of water jets as compared to a fabric with non-flat filaments;  
and

a structure that improves release of the fiber web from the hydroentangling fabric after entangling as compared to a fabric without said flat filaments.

In the spirit of advancing prosecution, Appellants added new claims 33 and 35 to positively recite the unexpected advantages of the flat filaments in the independent claims, although it is urged that the specification is ample evidence of the unexpected advantages discovered by the applicants, and hence supports the case for the patentability of the independent claims over the cited art. For evidentiary support of the unexpected advantages of the claimed flat filaments in hydroentangling support fabrics, Appellants refer to the quotes from the specification in the Summary of the Claims above. As requested by the Examiners, the specification evidences the many advantages of flat filaments in hydroentangling support fabrics over that of hydroentangling support fabrics, including but not limited to:

- a weave thickness  $T'$  that is smaller than the thickness  $T$ , wherein  $T$  represents a thickness without said flat filaments;
- a weave of more resistant to water flow in a direction perpendicular or substantially perpendicular to the plane in which a plurality of CD monofilaments lie;
- structure that reduces entangling of fibers to the fabric surface;
- improved MD/CD tensile ratios as compared to a fabric without said flat filaments; and
- improved release of the fiber web from the hydroentangling fabric after entangling.

As combined into a hydroentangling device for the production of a hydroentangled nonwoven product, the flat monofilaments, inter alia, promote greater reflective water flow, and therefore greater reflective entanglement energy. By promoting greater reflective entanglement energy, the fabric promotes greater entanglement of the fibers making up the nonwoven, and thereby provides for a stronger finished nonwoven. The Examiner gives no reason why these unexpected results would be foreseen or predicted by an ordinarily skilled artisan, improperly relying the notion of “intended use.” Although Appellants do not concede that a *prima facie* rejection has been made, a showing of unexpected results can overcome such a rejection. In the present case, the Examiner has not answered or otherwise addressed these unexpected results *qua* unexpected results to rebut a rejection, relying instead on the unsupported notion that of an “intended use.”

For these reasons, the rejection over Noelle fails under §§ 102 and 103. Appellants thus respectfully request that this Honorable Board reverse these rejections and mandate allowance of the claims.

#### V. THE CLAIMS ARE PATENTABLE OVER ZLATKUS

Claims 1-2, 4, 6, 13, 23, 25-27, 31, and 33-36 are rejected under §102 or §103 over Zlatkus.

##### *Independent Claims 1 and 23*

Zlatkus has no disclosure of flat filaments. Column 2, lines 32-52, column 3, lines 21-29, cited by the Examiner, states:

Turning to FIG. 1, a pictorial representation of the layering format necessary to practice the present invention illustrated by several examples. Two wood pulp fiber layers are shown on top of a foam layer utilizing either open or closed cell foam. In the diagrams, two layers of wood pulp tissue of 20 grams/m<sup>2</sup> were combined, although a single layer of 40 grams/m<sup>2</sup> provides the same or similar end products. **In example 2, flat wire 10 is utilized as a backing in the hydroentanglement process to provide a bearing surface for water jets 20 to work three separate constitute layers of the material.** In example 4, the same two layers of wood pulp fabric are utilized against a third layer of a suitable foam utilizing a **medium knuckle wire 12** as a bearing surface against which water jets 20 work the material for hydroentanglement. Good results have also been obtained by utilizing the same layering of material as shown in example 6 utilizing **high knuckle wire 14** to provide courser texturing of the final product. It is also possible to layer wood pulp fabric on either side of the center layer of suitable foam material as shown in example 8 against flat wire 16 to produce a useful composite.

The description contrasts “flat wire” backing as against “medium-knuckle wire” and “high-knuckle wire.” These descriptions, however, do not refer to the shape of the wire, but rather, to the configuration of the wire in the fabric. This is clear in Figure 1, as shown below:

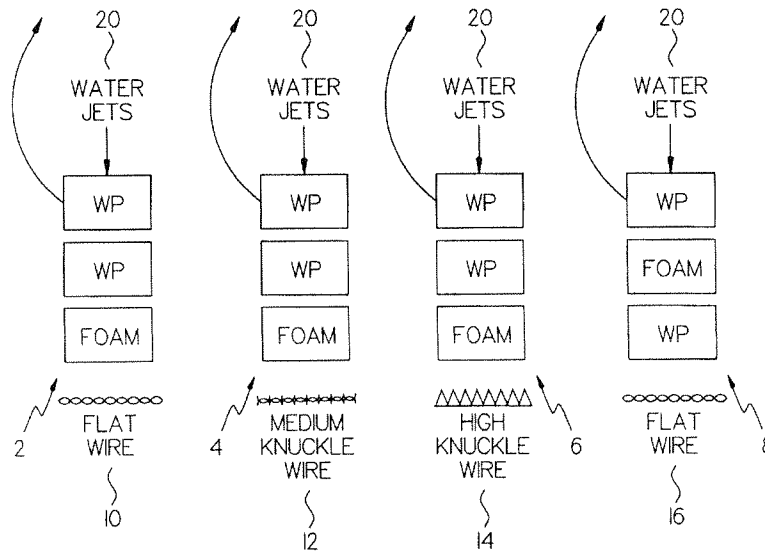


Fig. 1

As can be seen, the flat wire 10 has a substantially knuckle-free surface, or “flat” surface, as compared to the medium knuckles on the medium knuckle wire, and the high knuckles on the high knuckle wire. Thus the **“flat wire 10 is utilized as a backing in the hydroentanglement process to provide a bearing surface for water jets 20”** refers not to the shape of the wire filament itself, but refers to the bearing surface provided. A flat wire is the name of the flat surface, the medium knuckle wire is the name of the surface with medium knuckles, and a high knuckle wire is the name of the surface with high knuckles.

As the Figures show, the flatness and the knuckle sizes are not a function of the shape of the wire filament itself, but rather, how the mesh of the wire is formed. **The Examples of Zlatkus support this, as the Examples all refer to mesh stainless steel, and do not indicate that the wire should be anything but conventional round wire.** As such the reference fails to disclose a “hydroentangling support fabric...comprising flat filaments,” as required by the claims. As Zlatkus lacks a recited feature of the claim, the reference fails to support a *prima facie* case under 102.

As for §103, first, as amply laid out and evidenced in the prior responses and above, the claimed flat filaments provide unexpected advantages over hydroentangling

support fabrics without this structure. See the Summary, *supra*. These advantages have not been addressed.

The Examiner cites column 3 lines 21-29 of Zlatkus which states:

It is believed by the inventor that by the utilization of open or closed cell foams in the hydroentanglement process, the embedded fibers from the fibrous layers are locked into the cell structure and are less easily dislodged due to a tortious path through the "z" direction, and the cell pour size reduction. **Modification of the backing wire as shown in FIG. 1 assist in producing different textures or patterns as might be desirable in different applications.**

As is clear, most of the paragraph refers to a foam. The sentence that refers to the backing wire has a very broad suggestion of modifying the backing wire to produce different patterns or textures. This does not, however, suggest the very specific advantages of a **flat filament** or provide any motivation therefor. To the contrary, as Figure 1's variations of backing wire to produce different textures change the **configuration of the mesh or surface formed by the wire**. For example, Zlatkus states: "...as shown in example 6 utilizing **high knuckle wire 14 to provide courser texturing** of the final product." Col. 2, lines 49-50, cited above. Nothing in Zlatkus indicates that an ordinarily skilled artisan would or should use a different shaped filament, much less the claimed "flat filament" to effect such a modification.

At page 25 of the Final Office Action, the Examiner *for the first time* alleged Applicants' argument is not persuasive because "limitations from the specification are not read into the claims," stating the claim "does not recite a flat cross-sectional shape." This new, heretofore unrevealed interpretation of the claims in a Final Office Action is in error. During patent examination, the pending claims must be "given their broadest reasonable interpretation consistent with the specification. The Federal Circuit's en banc decision in *Phillips v. AWH Corp.*, 415 F.3d 1303, 75 USPQ2d 1321 (Fed. Cir. 2005) expressly recognized that the USPTO employs the 'broadest reasonable interpretation' standard.... The broadest reasonable interpretation of the claims must also be consistent with the interpretation that those skilled in the art would reach. *In re Cortright*, 165 F.3d 1353, 1359, 49 USPQ2d 1464, 1468 (Fed. Cir. 1999)." MPEP §2111. The broadest reasonable construction rubric standard "...does not give the PTO an unfettered license to interpret claims to embrace anything

remotely related to the claimed invention. Rather, claims should always be read in light of the specification and teachings in the underlying patent.” *In re Suitco Surface* (CAFC 2009-1418) (Decided April 14, 2010).

The claims expressly recite: “a hydroentangling support fabric having the mechanical properties and structural strength to reflect liquid jetted from the hydroentangling apparatus and comprising **flat filaments**.” Thus the claim requires the **filaments** be flat. To interpret this claim to include a fabric that does not include flat filaments is an unreasonable interpretation. As shown by the prior response, Zlatkus’s flat wire, medium knuckle wire and high knuckle wire backings in no way refer to filaments. It is sheer sophistry to assert this as a basis to adopt a new, absurd interpretation in a Final Office Action, whereby “flat filaments” could be interpreted to include filaments that do not have a flat cross section, particularly in light of the specification and teachings of the present specification that must inform the interpretation. The interpretation is a naked attempt to force the art to fit the rejection when it clearly does not, and should be treated as an admission that the Examiner concedes that Zlatkus does not in fact teach a flat filament as claimed.

For these reasons, the rejection over Zlatkus fails under §§ 102 and 103. Appellants thus respectfully request that this Honorable Board reverse these rejections and mandate allowance of the claims.

## VI. THE CLAIMS ARE PATENTABLE OVER GASSIER IN VIEW OF STRANDQVIST

Claims 1-2, 4, 6, 13, 23, 25-27, 31, and 33-36 are rejected under 35 U.S.C. §103 over Gassier in view of Strandqvist.

### *Independent claims 1 and 23*

The Examiner’s rejection is based **wholly** on the predicate that “Strandqvist discloses that it is known in the hydroentangling apparatus art to use a support fabric from a papermaking apparatus” and that they are “substantially identical.” Page 11-12 and 25-26 of the Final Office Action. The Examiner cites Strandqvist as evidence that Gassier’s dryer fabric, this time asserting that “Strandqvist discloses that it is known in the hydroentangling apparatus art to use a support fabric from a papermaking apparatus.” This is an

oversimplification of Strandqvist. Page 4, lines 7-11 of Strandqvist, cited by the Examiner, states:

The supporting member 12 which supports the fibre web during the hydroentanglement is constituted of a moulded, close-meshed plastic screen, for example the type disclosed in WO 92/1763 or in WO 98/35742, and which according to these documents is utilized as a **base material** for a **press felt** of a paper machine.

Emphasis added. Thus Strandqvist's support member "is utilized as a **base material** for a **press felt** on a papermaking machine." Gassier is a **dryer fabric** for a papermaking machine, **not a press felt**. **Press felts and dryer fabrics are not interchangeable fabrics on papermaking machines**. An ordinarily skilled artisan would not understand from this teaching that Strandqvist shows dryer fabrics are used as a support fabric in a hydroentangling apparatus.

To the contrary, Gaisser itself teaches away from using dryer fabrics as press felts. On press felts, Gaisser states at column 2, lines 23-29: "These **press felt base fabrics** are preferably woven endless. Due to **quite different objectives in designing these fabrics**, none of the designs show a structurally stable weave pattern and a projected open area in the range of thirty percent or more as in the case of the present invention." Emphasis added. Thus not only are Gaisser's dryer fabrics too different from press felts to ascribe any inherency on papermaking machines – much less for the completely different process of hydroentangling – but Gassier expressly teaches away from such a combination even within the context of papermaking.

At page 11 of the Final Office Action, the Examiner asserts the "reason" for the combination is that "it would have been obvious to use the support fabric of Gassier in a hydroentangling apparatus, motivated by a desire to construct a functioning hydroentangling apparatus." This is the very epitome of a conclusory statement. An examiner should not rely on conclusory statements that a particular feature of the invention would have been obvious or was well known. See *KSR v. Teleflex*, 550 U.S. at 418, citing *In re Kahn*, 441 F.3d 977, 988 (Fed. Cir. 2006) ("[R]ejections on obviousness grounds cannot be sustained by mere conclusory statements; instead, there must be some articulated reasoning with some rational underpinning to support the legal conclusion of obviousness."). Thus

the Examiner fails to make a *prima facie* case, and the burden to rebut such a case has never fallen to the Appellant.

Nonetheless, despite the utter lack of rational underpinning to the Examiner's reasoning, Appellants have provided remarks and evidence of record to show that even assuming for the sake of argument some areas of overlap, there are significant differences and structural requirements for different kinds of industrial fabrics, depending on the industrial machine upon which they are implemented. In the present case, the evidence shows that hydroentangling fabrics are not equivalent to dryer fabrics, much less "known equivalents."

Hydroentangling and papermaking processes and devices have wholly different needs. For a non-limiting example that highlights such difference, paragraph 31 of the publication of the Specification (hereafter the Specification) states:

The fabrics of the invention may be formed as single, double or triple layer weaves.... In such embodiment, the fibers of the nonwoven are supported by the round monofilaments of the forming side while the flat monofilaments promote **greater reflective water flow**, and therefore **greater reflective entanglement energy**, the fabric **promotes greater entanglement of the fibers making up the nonwoven, and thereby provides for a stronger finished nonwoven**. That is, when water is directed at the fabric in a direction perpendicular, or substantially perpendicular to the plane in which the flattened yarns lie, some **water will pass through the forming surface layer and intermediate layer, reflect off the wearside layer, and further entangle the fibers**. (Emphasis added)

Thus the design of the hydroentangling fabric requires, *inter alia*, permeability, and yet must **reflect** water from hydroentangling jets. All hydroentangling fabrics (1) have permeability and (2) reflect water at its surface and/or layers. Hydroentangling fabrics can comprise one or more layers, and may vary the areas for reflection and permeability, and indeed, one of the improvements of the present fabric with flat filaments is that it allows, in multi-layer fabrics, as explained above, reflection at the wearside as well. But every fabric must have permeability and the structure to provide the appropriate reflective water flow to effect entanglement.

Gassier, on the other hand explains how its papermaking fabrics must have different structural qualities. At col. 3, lines 16-19, Gassier states:

A fabric having increased fabric stability in the machine direction is provided yet having **a high degree of openness and permeability** in a range **greater than thirty percent** of the total fabric area.

And at col. 4, lines 26-28:

The drying process is outwardly from the heated cylinders through the paper web and through the dryer fabric. Thus **sufficient permeability must be had in order to facilitate drying of the fabric.**

And at Col. 6, lines 8-11:

Increased structural stability is provided in the machine direction **without decrease in the permeability or open area** of the fabric.

And at Col. 1, lines 30-36:

For drying purposes, the carrier fabric must have **a high degree of openness and air permeability so that sufficient air is delivered through the base fabric and the embossed layer, which is also permeable for drying.** Carrier fabric must have sufficient load bearing capability for bearing the loads in the machine direction which are the most severe.

Thus, it is clear that Gassier's highly permeable dryer fabric is in no way designed for hydroentangling.

Thus as evidenced above, in hydroentangling, the non-woven web is dry when on the forming fabric; thus drying and pressing are not functions reasons for a combination in hydroentangling. In particular, increasing the surface area is contrary to the need for permeability, and there is no need for reflectivity in a dryer fabric. This evidence has never been addressed.

Appellants also noted that the differences between dryer fabrics and hydroentangling fabrics that the latter are typically less permeable than dryer fabrics, as amply demonstrated by the evidence of the prior responses. For example dryer fabrics generally have permeabilities on the order of 1000-1200cfm (see Gassier at col. 4, lines 50-54), whereas hydroentangling fabrics are less, with the embodiments of the present

application described as being on the order of greater than 350cfm. See the present application at page 11, lines 8-9. Thus while there may putatively be some overlap between, for example, the permeabilities of such fabrics, in view of the other differing requirements of hydroentangling fabrics, such as reflection and entanglement, from dryer fabrics, Appellants urge that the unexpected results of the claimed flat filaments evinced herein overcome any putative *prima facie* case under §102 or §103. See, inter alia, MPEP 2131.03:

“Applicant can rebut a presumption of obviousness based on a claimed invention that falls within a prior art range by showing “(1) [t]hat the prior art taught away from the claimed invention...or (2) that there are new and unexpected results relative to the prior art.” *Iron Grip Barbell Co., Inc. v. USA Sports, Inc.*, 392 F.3d 1317, 1322, 73 USPQ2d 1225, 1228 (Fed. Cir. 2004).”

Thus the overwhelming evidence shows it was not, nor would it have been, “obvious to use the support fabric of Gassier in a hydroentangling apparatus, motivated by a desire to construct a functioning hydroentangling apparatus,” as alleged by the Examiner.

In the face of this evidence, the Examiner has articulated no reason to use a **dryer fabric** in a hydroentangling apparatus. Appellants clearly argued that Gassier teaches away from using dryer fabrics as press felts **even within the context of papermaking, which is not the same as hydroentangling**. The teaching away of Gassier demonstrates that dryer fabrics and press felts are not interchangeable equivalents. As the Examiner has given no other basis for the combination whatsoever, the argument more than rebuts the Examiner’s conclusory remarks that “it would have been obvious to use the support fabric of Gassier in a hydroentangling apparatus, motivated by a desire to construct a functioning hydroentangling apparatus,” or that they are “substantially identical.”

*Dependent claims 33 and 35*

Claims 33 and 35 recite:

The [apparatus of claim 1 /support fabric in the hydroentangling apparatus of claim 23] wherein said the flat filaments of the support fabric are incorporated into the structure of the fabric such that they include mechanical and structural properties, the mechanical and structural properties being selected from the group consisting of:

a weave thickness  $T'$  that is smaller than a thickness  $T$ , wherein  $T$  represents a thickness without said flat filaments;

a weave more resistant to water flow in a direction perpendicular or substantially perpendicular to the plane in which a plurality of CD monofilaments lie as compared to a fabric without said flat filaments;

a structure that reduces entangling of fibers to the fabric surface as compared to a fabric without said flat filaments;

improved MD/CD tensile ratios as compared to a fabric without said flat filaments;

a structure that improves the fabric's reflection of water jets as compared to a fabric with non-flat filaments;  
and

a structure that improves release of the fiber web from the hydroentangling fabric after entangling as compared to a fabric without said flat filaments.

In the spirit of advancing prosecution, Appellants added new claims 33 and 35 to positively recite the unexpected advantages of the flat filaments in the independent claims, although it is urged that the specification is ample evidence of the unexpected advantages discovered by the applicants, and hence supports the case for the patentability of the independent claims over the cited art. For evidentiary support of the unexpected advantages of the claimed flat filaments in hydroentangling support fabrics, Appellants refer to the quotes from the specification in the Summary of the Claims above. As requested by the Examiners, the specification evidences the many advantages of flat filaments in hydroentangling support fabrics over that of hydroentangling support fabrics, including but not limited to:

- a weave thickness  $T'$  that is smaller than the thickness  $T$ , wherein  $T$  represents a thickness without said flat filaments;
- a weave of more resistant to water flow in a direction perpendicular or substantially perpendicular to the plane in which a plurality of CD monofilaments lie;

- structure that reduces entangling of fibers to the fabric surface;
- improved MD/CD tensile ratios as compared to a fabric without said flat filaments; and
- improved release of the fiber web from the hydroentangling fabric after entangling.

As combined into a hydroentangling device for the production of a hydroentangled nonwoven product, the flat monofilaments, inter alia, promote greater reflective water flow, and therefore greater reflective entanglement energy. By promoting greater reflective entanglement energy, the fabric promotes greater entanglement of the fibers making up the nonwoven, and thereby provides for a stronger finished nonwoven. The Examiner gives no reason why these unexpected results would be foreseen or predicted by an ordinarily skilled artisan, improperly relying on conclusory remarks that “it would have been obvious to use the support fabric of Gassier in a hydroentangling apparatus, motivated by a desire to construct a functioning hydroentangling apparatus,” or that they are “substantially identical.” Although Appellants do not concede that a *prima facie* rejection has been made, a showing of unexpected results can overcome such a rejection. In the present case, the Examiner has not answered or otherwise addressed these unexpected results *qua* unexpected results to rebut a rejection, relying instead on the conclusory and unsupported remarks above.

For these reasons, none of which the Examiner acknowledged or weighed, the rejections on Gassier alone or Strandqvist in view of Gaisser fails under § 103. Appellants thus respectfully request that this Honorable Board reverse these rejections and mandate allowance of the claims.

## **VII. THE CLAIMS ARE PATENTABLE OVER GREENWAY IN VIEW OF EITHER NOELLE, ZLATKUS OR FAGERHOLM**

Claims 1-2, 4, 6, 13, 23, 25-27, 31, and 33-36 are rejected under §103 over Greenway in view of any one of Noelle, Zlatkus or Fagerholm.

### *Independent Claims 1 and 23*

As explained in detail in the prior responses, Greenway clearly discloses the use of round wires. Thus again, a person of ordinary skill in the art would not be motivated to combine the teachings of Gassier with that of Greenway merely because Greenway

discloses a hydroentangling 'module.' Also, Table I disclosed in col. 5, lines 45-60 of Greenway and cited by the Examiner, shows the following specifications for its forming screen:

TABLE I		
Forming Screen Specifications		
Property	36 × 29 flat	16 × 14 flat
Warp wire - Polyester	.0157	.032
Round		
Shute wire - Polyester	.0157	.035
Round		
Weave type	plain mesh	plain mesh
Open area	23.7%	24.9%
Plane difference	—	.008° ± .003
Snag	light	none ± light
Weave tightness (slay)	no angular displacement	no angular displacement
Edges	filled $\frac{1}{2}$ " each side	filled $\frac{1}{2}$ " each side
Seam	invisible/endless	invisible/endless

Greenway also discloses that entangling member 44 in FIG. 4A, which is a 36x29 mesh weave having a 24% void area, is **fabricated of polyester warp and shute round wire.** (Greenway -- col. 5, lines 14-17). Therefore, Greenway discloses the use of round wires for its forming screen and there is no reason for one skilled in the art to modify the forming wire of Greenway when there is clearly no reason in Greenway to use wires of **other shapes.**

The deficiencies of Noelle and Zlatkus are outlined above, and for the same reasons, do not cure Greenway's deficiency here. In particular, paragraph [0038] of Zlatkus as discussed above, teach reconfiguring the raised and recessed portions of a fabric to achieve various textures, and not using a flat filament as the Examiner suggests. For the reasons given in more detail above, the evidence of record, including the specification and Noelle itself, proves the ordinarily skilled artisans distinguish a support fabric, which takes the form of a belt, from a covering for a drum. As such, and ordinarily skilled artisan would not interpret the term "hydroentangling support fabric," to include a covering for a drum, even adopting the broadest reasonable construction of that term uninformed by the specification, much less when read in light of the specification.

Fagerholm, like many of the previous references cited by the Examiner, teaches a fabric for a papermaking machine, and in particular, a dryer fabric. As explained in

more detail above with respect to Gassier, dryer fabrics are significantly different from hydroentangling support fabrics, with differing structures for differing functions. Also, as evidenced in the prior responses, the need for increased stability in higher degree of openness is not an issue in Greenway. Indeed, Fagerholm cites a different, contrary reason for using a flat filament to achieve a thinner fabric in the context of a dryer fabric – better contact with the web to be dewatered (col. 2, lines 13)—whereas in the present invention, it improved release of the fiber web from the hydroentangling fabric after entangling.

Thus again while there may putatively be some overlap between, for example, the permeabilities of dryer fabrics and hydroentangling fabrics, in view of the other differing requirements of hydroentangling fabrics, such as reflection and entanglement, from dryer fabrics, Appellants again urge that the unexpected results of the claimed flat filaments evinced herein overcome any putative *prima facie* case under 103. See MPEP 2144.05. “Applicant can rebut a presumption of obviousness based on a claimed invention that falls within a prior art range by showing “(1) [t]hat the prior art taught away from the claimed invention...or (2) that there are new and unexpected results relative to the prior art.” *Iron Grip Barbell Co., Inc. v. USA Sports, Inc.*, 392 F.3d 1317, 1322, 73 USPQ2d 1225, 1228 (Fed. Cir. 2004).”

*Dependent claims 33 and 35*

As explained in more detail above in the Summary of the Claims and the rejections already discussed with respect to claims 33 and 35, the specification evidences the many advantages of flat filaments in hydroentangling support fabrics over that of hydroentangling support fabrics, including but not limited to:

- a weave thickness T' that is smaller than the thickness T, wherein T represents a thickness without said flat filaments;
- a weave of more resistant to water flow in a direction perpendicular or substantially perpendicular to the plane in which a plurality of CD monofilaments lie;
- structure that reduces entangling of fibers to the fabric surface;
- improved MD/CD tensile ratios as compared to a fabric without said flat filaments; and

- improved release of the fiber web from the hydroentangling fabric after entangling.

As combined into a hydroentangling device for the production of a hydroentangled nonwoven product, the flat monofilaments, inter alia, promote greater reflective water flow, and therefore greater reflective entanglement energy. By promoting greater reflective entanglement energy, the fabric promotes greater entanglement of the fibers making up the nonwoven, and thereby provides for a stronger finished nonwoven. The Examiner gives no reason why these unexpected results would be foreseen or predicted by an ordinarily skilled artisan. Although Appellants do not concede that a *prima facie* rejection has been made, even assuming for the sake of argument the reasons given by the Examiner articulate a *prima facie* case for the combination above, a showing of unexpected results can overcome such a rejection. In the present case, the Examiner has not answered or otherwise addressed these unexpected results *qua* unexpected results to rebut a rejection.

For these reasons, the rejection over Greenway in view of any one of Noelle, Zlatkus or Fagerholm fails under § 103. Appellants thus respectfully request that this Honorable Board reverse these rejections and mandate allowance of the claims.

#### VIII. THE CLAIMS ARE PATENTABLE OVER STRANDQVIST IN VIEW OF LEWIS

Claims 1-2, 4, 6, 13, 23, 25-27, 31, and 33-36 are rejected under 103 over Strandqvist in view of Lewis.

##### *Independent Claims 1 and 23*

As acknowledged by the Examiner throughout prosecution, Strandqvist does not mention the use of rectangular filaments. Lewis is a general teaching for a ribbon reinforced composite. The ribbons are shown as a substitute for fibers in a composite. See col. 1, lines 35-54 cited by the Examiner. Lewis fails to teach a flat **filament**. Lewis describes a polymeric composition/matrix which is reinforced with rectangular fibers – the ribbons. **The reference is for forming ribbon reinforced composites, not filaments, and not filaments for a fabric.** Thus Lewis is wholly deficient for the claimed feature it is cited for.

As for the reason for combination, the Office Action proffers the substitution for the “round reinforcement filament shape of Strandqvist with the flat shape

of Lewis motivated by the desire to provide substantial biaxial reinforcement to the polymeric screen.” A wire reinforcement in a screen, however, is **not equivalent to a fiber in a polymeric matrix for a composite**. Thus there is no basis whatsoever for this assumption.

The Examiner’s entire response at page 26 of the Final Office Action is thus: “Lewis discloses that the invention pertains to fibers with a rectangular cross section (col. 1, lines 5-8).” As cited, Lewis states: “The invention pertains to polymeric compositions reinforced with fibers having a substantially rectangular cross-section. Fibers with such a geometric configuration are referred to here as ribbons.” Again, an ordinarily skilled artisan would not regard a ribbon or fiber for reinforcing a polymeric composite as a filament for a fabric, much less a hydroentangling support fabric.

*Dependent claims 33 and 35*

As explained in more detail above in the Summary of the Claims and the rejections already discussed with respect to claims 33 and 35, the specification evidences the many advantages of flat filaments in hydroentangling support fabrics over that of hydroentangling support fabrics, including but not limited to:

- a weave thickness T' that is smaller than the thickness T, wherein T represents a thickness without said flat filaments;
- a weave of more resistant to water flow in a direction perpendicular or substantially perpendicular to the plane in which a plurality of CD monofilaments lie;
- structure that reduces entangling of fibers to the fabric surface;
- improved MD/CD tensile ratios as compared to a fabric without said flat filaments; and
- improved release of the fiber web from the hydroentangling fabric after entangling.

As combined into a hydroentangling device for the production of a hydroentangled nonwoven product, the flat monofilaments, inter alia, promote greater reflective water flow, and therefore greater reflective entanglement energy. By promoting greater reflective entanglement energy, the fabric promotes greater entanglement of the fibers making up the nonwoven, and thereby provides for a stronger finished nonwoven. The Examiner gives no

reason why these unexpected results would be foreseen or predicted by an ordinarily skilled artisan. Although Appellants do not concede that a *prima facie* rejection has been made, even assuming for the sake of argument the reasons given by the Examiner articulate a *prima facie* case for the combination above, a showing of unexpected results can overcome such a rejection. In the present case, the Examiner has not answered or otherwise addressed these unexpected results *qua* unexpected results to rebut a rejection.

For these reasons, the rejection over Strandqvist over Lewis fails under §§ 102 and 103. Appellants thus respectfully request that this Honorable Board reverse these rejections and mandate allowance of the claims.

#### **IX. DEPENDENT CLAIMS**

Nothing in the cited art of record cures the deficiencies of the art as applied to independent claims 1 and 23. For the sake of more organized presentation of the issues, certain of the dependent claims are addressed under the headings given rejections. Save for claims 33-36 where argued separately above under such rejections as articulated above, the dependent claims stand or fall with independent claims 1 and 23. Appellants thereby respectfully request reversal of the rejections and allowance of the claims by this Honorable Board.

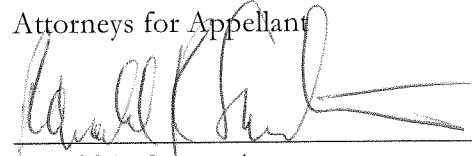
**CONCLUSION**

For the reasons discussed in this brief and the arguments of record (both recited herein and incorporated herein by reference), instantly pending claims 1-2, 4, 6, 13, 23, 25-27, 31, and 33-36 are patentable. It is therefore submitted that the Examiner erred in rejecting claims 1-2, 4, 6, 13, 23, 25-27, 31, and 33-36, and Appellant requests a reversal of these rejections by this Honorable Board. As a result, the allowance of this application should be mandated.

Respectfully submitted,  
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**APPENDIX I**

**CLAIMS ON APPEAL**

What is claimed is:

1. (Previously Presented) A hydroentangling apparatus for the production of a hydroentangled nonwoven product, the improvement comprising:

a hydroentangling support fabric having the mechanical properties and structural strength to reflect liquid jetted from the hydroentangling apparatus and comprising flat filaments, wherein said support fabric is in a continuous loop or made endless.

2. (Previously Presented) The apparatus of claim 1, wherein said support fabric includes machine direction (MD) filaments and cross-machine direction (CD) filaments and said flat filaments include only a portion of said MD filaments.

3. (Withdrawn) The apparatus of claim 1, wherein said fabric includes MD filaments and CD filaments and said flattened filaments include all of said MD filaments.

4. (Previously Presented) The apparatus of claim 1, wherein said support fabric includes MD filaments and CD filaments and said flat filaments include only a portion of said CD filaments.

5. (Withdrawn) The apparatus of claim 1, wherein said fabric includes MD filaments and CD filaments and said flattened filaments include all of said CD filaments.

6. (Previously Presented) The apparatus of 1, wherein said support fabric includes MD filaments and CD filaments and said flat filaments include a combination of said MD filaments and said CD filaments.

7. (Previously Presented) The apparatus of claim 1, wherein said support fabric is a multilayer weave fabric and said flat filaments are incorporated into only one layer.

8. (Previously Presented) The apparatus of claim 7, wherein said one layer of said support fabric is the wear side layer.

9. (Withdrawn) The apparatus of claim 7, wherein said one layer of said support fabric is the forming side layer.

10. (Withdrawn) The apparatus of claim 1, wherein said fabric is a triple layer fabric and said flattened filaments are incorporated into only one layer.

11. (Withdrawn) The apparatus of claim 10, wherein said one layer of said fabric is the wear side layer.

12. (Withdrawn) The apparatus of claim 10, wherein said one layer is the forming side layer.

13. (Previously Presented) The apparatus of claim 1, wherein the permeability of said support fabric is greater than 350 cfm.

14-22. (Cancelled)

23. (Previously Presented) An improved hydroentangling support fabric in a hydroentangling apparatus for production of a hydroentangled nonwoven product, the improvement comprising:

said hydroentangling support fabric in the hydroentangling apparatus having the mechanical properties and structural strength to reflect liquid jetted from the hydroentangling apparatus and comprising flat filaments, wherein said support fabric is in a continuous loop or made endless.

24. (Withdrawn) The support fabric in the hydroentangling apparatus of claim 23, wherein said flattened filaments are formed through extrusion prior to weaving of said support fabric.

25. (Previously Presented) The support fabric in the hydroentangling apparatus of claim 23, wherein said flat filaments are formed by calendering non-flat filaments prior to weaving of said support fabric.

26. (Previously Presented) The support fabric in the hydroentangling apparatus of claim 23, wherein said flat filaments are formed by calendering a source fabric.

27. (Previously Presented) The support fabric in the hydroentangling apparatus of claim 26, wherein said calendering is applied to only one side of said source fabric.

28. (Withdrawn) The support fabric in the hydroentangling apparatus of claim 26, wherein said calendering is applied to both sides of said source fabric.

29. (Withdrawn) The support fabric in the hydroentangling apparatus of claim 23, wherein said flattened filaments are formed by sanding a source fabric.

30. (Cancelled)

31. (Previously Presented) The support fabric in the hydroentangling apparatus of claim 23, wherein said flat filaments are incorporated into said support fabric during production of said support fabric.

32. (Previously Presented) The support fabric in the hydroentangling apparatus of claim 23 wherein said support fabric includes a plurality of layers structured to allow water jetted from the hydroentangling apparatus to pass through a forming surface layer and an intermediate layer and reflect off the a wearside layer when said water is directed at the

fabric in a direction perpendicular, or substantially perpendicular to the plane in which the flattened yarns lie.

33. (Previously Presented) The apparatus of claim 1 wherein said the flat filaments of the support fabric are incorporated into the structure of the fabric such that they include mechanical and structural properties, the mechanical and structural properties being selected from the group consisting of:

a weave thickness  $T'$  that is smaller than a thickness  $T$ , wherein  $T$  represents a thickness without said flat filaments;

a weave more resistant to water flow in a direction perpendicular or substantially perpendicular to the plane in which a plurality of CD monofilaments lie as compared to a fabric without said flat filaments;

a structure that reduces entangling of fibers to the fabric surface as compared to a fabric without said flat filaments;

improved MD/CD tensile ratios as compared to a fabric without said flat filaments;

a structure that improves the fabric's reflection of water jets as compared to a fabric with non-flat filaments; and

a structure that improves release of the fiber web from the hydroentangling fabric after entangling as compared to a fabric without said flat filaments.

34. (Previously Presented) The apparatus of claim 1, wherein the liquid is jetted from the hydroentangling apparatus at pressures from at least 200 psi.

35. (Previously Presented) The support fabric in the hydroentangling apparatus of claim 23 wherein said the flat filaments of the support fabric are incorporated into the

structure of the fabric such that they include mechanical and structural properties, the mechanical and structural properties being selected from the group consisting of:

a weave thickness  $T'$  that is smaller than a thickness  $T$ , wherein  $T$  represents a thickness without said flat filaments;

a weave more resistant to water flow in a direction perpendicular or substantially perpendicular to the plane in which a plurality of CD monofilaments lie as compared to a fabric without said flat filaments;

a structure that reduces entangling of fibers to the fabric surface as compared to a fabric without said flat filaments;

improved MD/CD tensile ratios as compared to a fabric without said flat filaments;

a structure that improves the fabric's reflection of water jets as compared to a fabric with non-flat filaments; and

a structure that improves release of the fiber web from the hydroentangling fabric after entangling as compared to a fabric without said flat filaments.

36. (Previously Presented) The support fabric in the hydroentangling apparatus of claim 23, wherein the liquid is jetted from the hydroentangling apparatus at pressures of from at least 200 psi.

**APPENDIX II**  
**EVIDENCE**

1. Exhibit A: *Fibers Caught in the Knuckles of the Forming Wires: Experimental Measurements and Physical Origins of the Force of Peeling in the Hydroentanglement Process*, Abdelfattah Mohamed Seyam, Ph.D. Ping Xiang; Andrey V. Kuznetsov. Entered and considered as shown in the IDS attached with the Final Office Action on August 25, 2009.
2. Exhibit B: M.G. Kamath et al., Spunlace Hydroentanglement, from web site <http://hWeb.utk.edu/~mse/pages/textiles/spunlace.htm>. Entered and considered as shown in the IDS attached with the Final Office Action on August 25, 2009.
3. U.S. Patent 5,136,761 entered and considered as shown in the IDS attached with the Final Office Action on August 25, 2009.
4. U.S. Patent 6,163,943 (the '943 patent'), incorporated by reference at paragraph 12 of the published application, considered as shown in the IDS attached with the Office Action on December 21, 2005.
5. CA patent no 841,938, incorporated by reference into the '943 patent at col. 3, lines 54-56, and entered as shown in the IDS attached to the Office Action dated May 14, 2010.
6. U.S. 4,967,456 entered as shown in the IDS attached to the Office Action dated May 14, 2010.



## **EXHIBIT A**

# Fibers Caught in the Knuckles of the Forming Wires: Experimental Measurements and Physical Origins of the Force of Peeling in the Hydroentanglement Process

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## ABSTRACT

In hydroentanglement process, very fine water jets with high pressure impinge on the fiberweb, which is supported by forming wires. The impact of the jets causes fiber entanglement in the fiberweb and produces an integrated fabric with desired performance, texture, and appearance similar to the forming wires. It is important that at the end of the process, the fiberweb can be easily separated from the forming wires. In this paper, the force of peeling required for the separation of the wet, hydroentangled fabric from the forming wires is measured experimentally. A set of experimental trials was conducted to investigate the effects of the jet pressure, fiberweb basis weight, and forming wires mesh size on the peeling force. Visualizing fibers caught in the knuckles of the forming wires under magnification reveals physical mechanisms leading to the formation of the peeling force.

## INTRODUCTION

Hydroentanglement is a mechanical bonding process designed to produce nonwoven fabrics with the texture and appearance that resemble woven and knitted fabrics. In a typical hydroentanglement process, a row or multiple rows of highly pressurized, fine, closely spaced water jets impinge on a fiberweb, which is supported by forming wires (*Figure 1*). Due to the impact of water jets, fibers are displaced and rotated around other fibers that surround them, resulting in fibers twisting and entangling around the neighboring fibers. The fabric produced is held together by the fiber-to-fiber friction. For fibers located in the lower portion of the fiberweb close to the forming wires, it is quite usual to be pushed into the knuckles (the cross-over areas of MD and CD wires, see *Figure 5b*) of the forming

belt. This creates difficulty in separating the fabric from the forming wires. If the required peeling force is large, the structure and properties of the fabric may be compromised during fabric separation from the forming wires (see *Figure 2*). In *Figure 2*, the horizontal direction is the machine direction, and the fabric is separated from the forming belt from the right to the left in the MD (see the horizontal jet streaks on the fabric). The fabric in *Figure 2* is strongly distorted at the edge, and there is even a hole at the fabric edge, which resulted from fabric separation from the forming belt. Thus, if too many fibers are caught in the knuckles of the forming wires, the integrity of the fabric structure is negatively affected. Additionally, the process efficiency is drastically reduced as a result of stops to clean the belt from fibers. If the fibers caught by the forming wires are accumulated and not removed, the performance and texture of the resultant hydroentangled fabric suffer to a great extent.

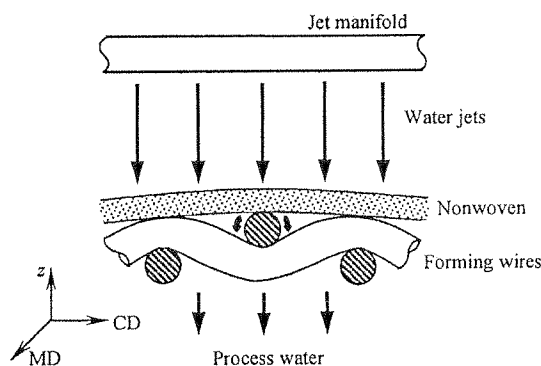


FIGURE 1: Typical cross-section of a hydroentanglement unit

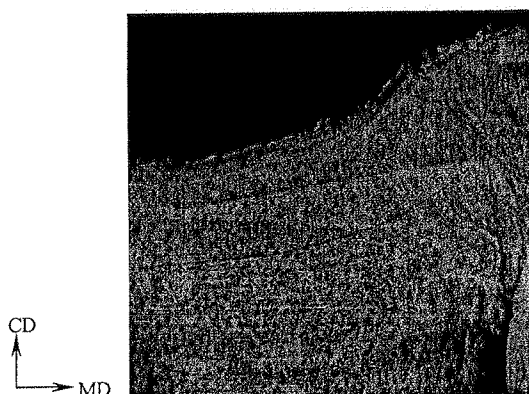


FIGURE 2. Fabric damage as a result of separating the fabric from the forming belt

A considerable amount of research was conducted on technology for hydroentanglement products and process parameters. The effect of the nozzle geometry on the water jet breakup and impact force in the hydroentanglement process was investigated experimentally and numerically in [1,2]. The cavitation and hydraulic flip inside hydroentanglement nozzles were also studied in [3,4]. Effects of the initial fiberweb geometry and pressure distribution between different manifolds of water jets on the properties of hydroentangled fabric were studied experimentally in [5]. The experimental investigation of the effect of fiberweb and fiber properties on the critical water jet pressure and energy consumption was presented in [6].

The fiber orientation and length distribution in hydroentangled fabrics were evaluated in [7] by analyzing two-dimensional SEM images. The relationships between the microstructural variables and fabric mechanical properties (strength and modulus), which were used to estimate the degree of entanglement in hydroentangled fabrics, were also analyzed. The structure-process-property relationships in hydroentangled nonwovens were developed through experimental studies reported in [8].

Research and development work was also focused on reducing the energy consumption in this process. Improving the injector, developing an efficient high pressure pumping system, better fiber composition and web forming method, as well as designing improved piping and vacuum systems were all used to reduce energy consumption [9]. The development of texture during hydroentanglement was examined in [10] as a function of hydroentangling energy. Research reported in [11] showed that

hydroentanglement can be combined with other bonding processes, such as chemical, thermal or hydrogen, to improve fabric properties and reduce the amount of hydroentangling energy required.

Communication with industry experts revealed that fiber entrapment around the forming wires and in the knuckles (and hence the peeling force) poses serious problems, as discussed above. Despite the significant effect of the peeling force on the final fabric properties, no systematic experimental research addressing the peeling force required to separate the fabric from the forming wires in the hydroentanglement process has been reported so far. The authors' previous work [12] was focused on the development of a model for the peeling force. The aim of this paper is to provide a fundamental understanding of the cause of peeling force through systematic experimental investigation of the effects of the process and web parameters (such as the jet pressure, fiberweb basis weight, and forming wires mesh size) and visualizing fibers left caught in the knuckles of the forming wires under magnification.

## EXPERIMENTAL PROCEDURE

### Sample processing and experimental design

To test the peeling force, samples of hydroentangled fabric were produced using Fleissner's hydroentanglement machine available at the facilities of NCRC at NCSU. Four woven forming belts (see Table I) were used in the hydroentanglement process, which were provided by the Albany International. The fiberweb and forming belt were moving at a controlled constant speed of 30 m/min.

The highly pressurized water jets impinging on the fiberweb have a diameter of 0.127 mm, and a density of 15.8 jets/cm (40 jets/inch). Two different carded and crosslapped webs with different basis weights (50 g/m<sup>2</sup> and 100 g/m<sup>2</sup>) were used. The polyester fiber used to form the webs is of linear density 0.168 g/km (1.68 dtex) and of fiber length 38 mm.

A total of 24 hydroentangled fabrics were produced (two basis weights x three pressure levels x four belts). The belts' specifications, pressure levels, and pressure distribution for each manifold are shown in Tables I and II. Each trial (for the same fabric) was repeated three times to produce total of six samples (two from each trial) five of which were used to measure the peeling force (and one was kept in reserve).

TABLE I. Geometrical parameters of the forming wires

Forming wires	Count (/cm) [/inch]	MD wire diameter (mm)	CD wire diameter (mm)	Open area (%)	Wire cross-section shape	Thickness (mm)
100 mesh	40.0 × 35.4 [100 × 90]	0.11	0.14	29	Round	1.6510
75 mesh	30.0 × 24.4 [75 × 62]	0.15	0.22	26	Round	0.6858
36 mesh	14.2 × 10.6 [36 × 27]	0.40	0.40	25	Round	0.3586
10 mesh	4.3 × 4.3 [11 × 11]	0.89	1.00	35	Round	0.2794

TABLE II. Pressure distribution of different manifolds

Pressure (MPa)		
Manifold No. 1	Manifold No. 2	Manifold No. 3
4	9	9
4	14	14
4	20	20

### Peeling force testing procedure

After the hydroentanglement process, the wet fabric samples have not been separated immediately from the forming belt. For each fabric/forming wires combination tested, five rectangular samples of the fabric attached to the forming wires of a size of 25 mm × 150 mm (CD × MD) have been cut after each trial.

The separation of the fabric from the forming belt is performed in the machine direction since this is how

it happens in real production. The peeling force was measured using a Sintech tensile tester shown in *Figure 3*. The gauge length between the two jaws initially (before the peeling process) is 75 mm, and the clamping grip pressure used is 10.34 MPa (1500 psi). Before testing the peeling force, the fabric has been partly separated from the forming wires for the length of about 50 mm; then the separated fabric was held in place in the upper jaw of the tensile tester, and the separated forming wire was held in place in the lower jaw (as shown in *Figure 3*). Once the peeling process was started, the upper jaw was moved upward with a constant speed of 0.3 m/min.

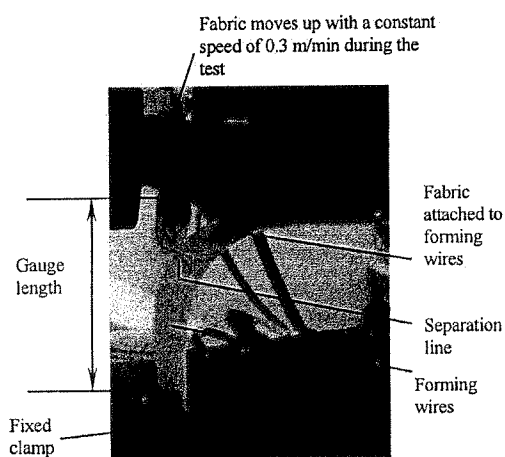


FIGURE 3. Initial state of the fabric partly separated from the forming wires before testing in the Sintech tester

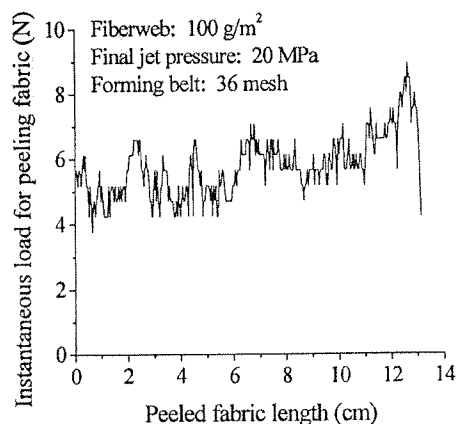


FIGURE 4. A typical graph obtained from the tensile tester

Figure 4 shows a typical graph obtained from the tensile tester. The graph shows only the portion of the distance-force relation after removal of the slackness of the sample. The peaks of the graph represent the instantaneous peeling force, and the average of these peaks is calculated to obtain the peeling force for a given sample. The peeling force of each fabric from a forming belt is calculated by averaging the peeling forces for five samples of the fabric.

## RESULTS AND DISCUSSION

### Peeling force results

The measured peeling forces for each fabric on different forming belts are summarized in Tables III through VI. These tables give the average value of the peeling force and the standard deviation. For most cases the standard deviation does not exceed 10% of the average value. The variation of the peeling force between the measurements is mostly due to the inhomogeneous structure of the fabric/forming belt interface. The peeling force is due to the fibers that are caught in the knuckles of the forming wires; the instantaneous peeling force varies as the separation proceeds from one knuckle to the

next; this is supported by the instantaneous peeling force data shown in Figure 4.

Photographs of the magnified structure of the forming belts after the belt was separated from the fabric are also taken to better understand physical phenomena that induce the peeling force. Figures 5 through 8 show magnified images taken for different webs and different forming belts at jet pressure of 20 MPa. Different magnification is used for different forming belts in order to clearly show the geometry of the forming wires as well as the fibers left caught in the knuckles (the magnifications on the same forming belts are the same for 50 g/m<sup>2</sup> and 100 g/m<sup>2</sup> webs, the exact magnifications are listed in the caption of the corresponding figure).

Figures 5 through 8 show that some fibers are left caught by the forming wires after the fabric is separated from the forming belt. It is evident that for the coarsest 10 mesh forming belt (Figures 5a and 5b), there are more fibers entangled around the forming wires and left caught in the knuckles than for the other forming belts. As the forming belt gets finer, there are fewer fibers left caught by the forming wires. This is especially true for the 100 mesh forming belt

TABLE III. Experimental peeling force data for 10 mesh forming belt

	Fabric processed with 50 g/m <sup>2</sup> web			Fabric processed with 100 g/m <sup>2</sup> web		
Final jet pressure (MPa)	9	14	20	9	14	20
Peeling force (N/cm)	2.800	3.675	3.850	2.625	2.945	3.325
Standard deviation (N/cm)	0.175	0.225	0.280	0.350	0.263	0.175

TABLE IV. Experimental peeling force data for 36 mesh forming belt

	Fabric processed with 50 g/m <sup>2</sup> web			Fabric processed with 100 g/m <sup>2</sup> web		
Final jet pressure (MPa)	9	14	20	9	14	20
Peeling force (N/cm)	2.450	3.150	3.325	2.275	2.675	2.975
Standard deviation (N/cm)	0.225	0.085	0.350	0.140	0.175	0.263

TABLE V. Experimental peeling force data for 75 mesh forming belt

	Fabric processed with 50 g/m <sup>2</sup> web			Fabric processed with 100 g/m <sup>2</sup> web		
Final jet pressure (MPa)	9	14	20	9	14	20
Peeling force (N/cm)	2.100	2.625	2.800	1.925	2.275	2.450
Standard deviation (N/cm)	0.175	0.085	0.225	0.085	0.350	0.263

TABLE VI. Experimental peeling force data for 100 mesh forming belt

	Fabric processed with 50 g/m <sup>2</sup> web			Fabric processed with 100 g/m <sup>2</sup> web		
Final jet pressure (MPa)	9	14	20	9	14	20
Peeling force (N/cm)	1.925	2.275	2.625	1.750	1.925	2.100
Standard deviation (N/cm)	0.105	0.175	0.070	0.085	0.035	0.158

(Figures 8a and 8b), where very few fibers are left caught in the knuckles. From the results given in Tables III through VI, it is evident that when the other process parameters are the same, the peeling force for a coarser mesh forming belt is larger than that for a finer mesh forming belt. Combining the information gained from the peeling force measurements and magnified photographs of the forming belt, it is concluded that the more fibers are caught in the knuckles of the forming belt, the larger is the peeling force required to separate the fabric from the forming belt.

Comparing the microscopic structures for different fiberwebs on the same forming belt, it is found that when the other processing conditions are the same, more fibers are caught by the forming wires for the fiberweb with a smaller basis weight after the fabric is separated. This is explained by the fact that it is easier for the water jets to penetrate through the lighter weight web, resulting in pushing more fibers into the knuckles of the forming belt. This phenomenon is obvious for the 10 mesh, 36 mesh and 75 mesh forming belts (see Figures 5 through 7). The effect of the fiberweb basis weight is not significant for the 100 mesh forming belt (see Figure 8). This is because so few fibers are caught by the 100 mesh forming wires regardless of the fiberweb basis weight. The corresponding peeling force results given in Tables III through VI also indicate that on any given type of the forming belt, the peeling force required to separate the fabric with a smaller basis weight is larger when the water jet pressure is the same.

The peeling force results of Tables III through VI also support the conclusion that on any given type of a forming belt, the peeling force increases with the increase of the jet pressure for a given basis weight fiberweb.

From the above observations, it is concluded that the primary reason why a force is required to separate the

fabric from the forming belt is fiber entrapment in the knuckles of the forming wires.

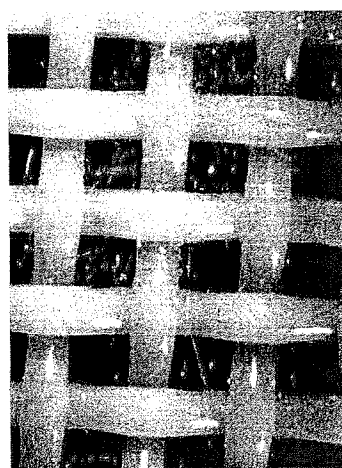
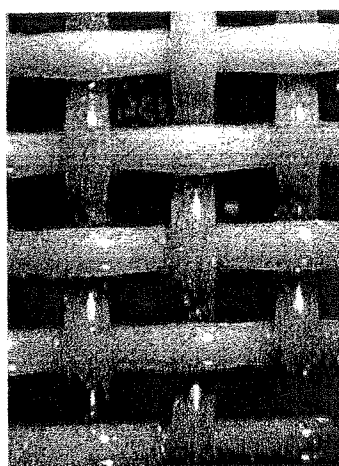
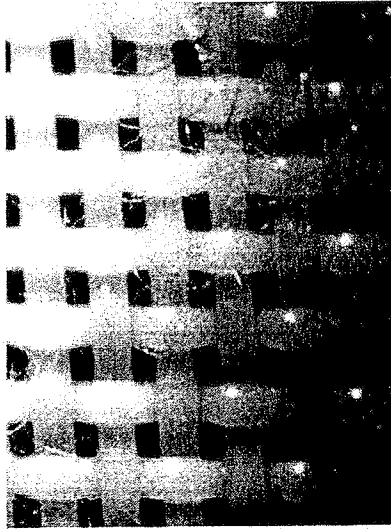
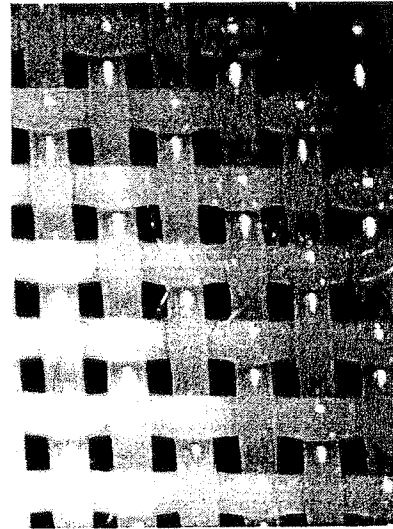
(a) 50 g/m<sup>2</sup> web(b) 100 g/m<sup>2</sup> web

FIGURE 5. Magnified photographs of 10 mesh forming belts after fabric has been removed from them (final jet pressure: 200 bar, magnification: 0.8)



(a) 50 g/m<sup>2</sup> web

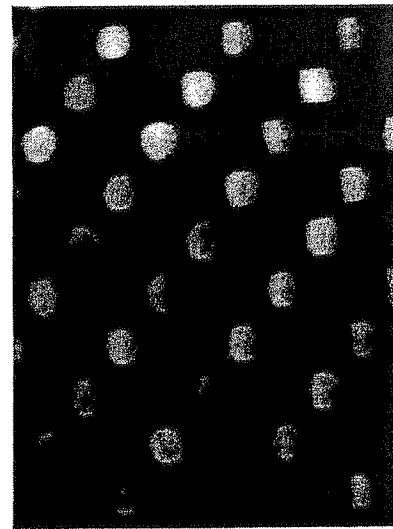


(b) 100 g/m<sup>2</sup> web

FIGURE 6. Magnified photographs of 36 mesh forming belts after fabric has been removed from them (final jet pressure: 200 bar, magnification: 1.5)

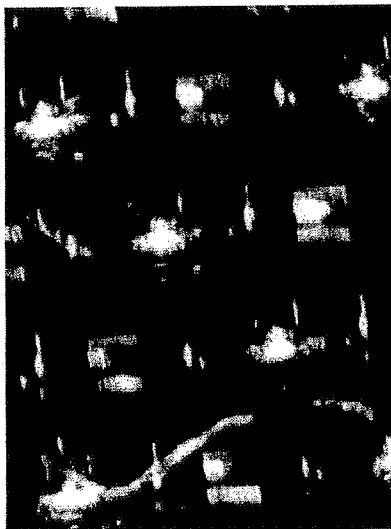


(a) 50 g/m<sup>2</sup> web

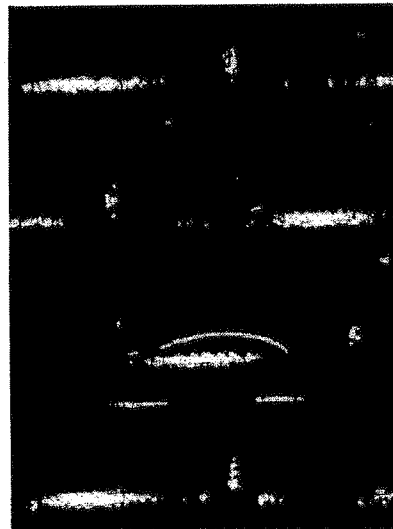


(b) 100 g/m<sup>2</sup> web

FIGURE 7. Magnified photographs of 75 mesh forming belts after fabric has been removed from them (final jet pressure: 200 bar, magnification: 3.0)



(a) 50 g/m<sup>2</sup> web



(b) 100 g/m<sup>2</sup> web

FIGURE 8. Magnified photographs of 100 mesh forming belts after fabric has been removed from them (final jet pressure: 200 bar, magnification: 5.0)

The physical reason why some fibers are caught in the knuckles of the forming wires is the entangling effect of the water jets, which, in addition to entangling fibers, also push some of the fibers into the spaces between the forming wires, rotate the fibers around the forming wires, and push the fibers into the knuckles. The mechanism of fiber entrapment in the knuckles can be described as follows. The impinging water induces vortices as it passes through the fiberweb and the voids between the forming wires. Due to the rotational effect of the water vortices, fibers swirl with water. By the combined effect of jet pressure and vorticity, some fibers are pushed directly into the knuckles, some other fibers are entangled around the forming wires in the MD-CD plane. The fibers entangled around the forming wires are then shifted and pushed into the knuckles by the water flow. As a result, most fibers entangled around the forming wires end up getting caught between the wires at knuckles; this leads to the force of peeling required for separating the fiberweb from the forming wires.

The fabric is strongly affected by the peeling process. Generally, for a larger peeling force, the regularity of the fabric is worse and there is higher probability to have damage on the fabric. For example, for the 50 g/m<sup>2</sup> web on the 10 mesh forming belt, the fabric is strongly distorted after the separation. However, for

the webs on the 100 mesh forming belt, the fabric exhibits only a very minor distortion after the separation from the forming belt. Typical fabric damage resulting from separating the fabric from the forming belt is shown in *Figure 2*.

#### Prediction of the effect of separation speed

The speed of separation of the fabric from the forming belt used in the experiments reported in this paper is 0.3 m/min, which is due to specifications of the Sintech tensile tester used in this research. This is significantly lower than a speed of separation used in industry for a typical hydroentanglement process (30 m/min). In this section an equation that predicts how to rescale the results obtained in the experiments for the case of a different separation speed is developed.

To better understand physical phenomena during the separation, the lengths of the fibers that are left caught in the knuckles after the separation are measured and the results are summarized in *Table VII*. The forming wires were cut and the fibers caught in the knuckles were carefully removed from the belts without breaking the fibers. With the aid of a ruler, the length of each fiber was measured. The fibers were manually straightened by removing the crimp without stretching. It is found that most fibers that are caught in the knuckles are broken during the separation process. This suggests that the dependence

of the peeling force on the separation velocity can be deduced from the relation between tenacity and rate of extension, which is given in [13] as:

$$F_1 - F_2 = kF_1 \log_{10}(t_2/t_1) \quad (1)$$

where  $F_1$  is the breaking load if the fiber breaks over the time interval  $t_1$ ,  $F_2$  is the breaking load if the fiber breaks over the time interval  $t_2$ , and  $k$  is the strength-time coefficient. Values of the constant  $k$  are given in ref. [13] for different types of fibers. Thus, the peeling force  $F_p$  at a different separation speed can be estimated as:

$$F_{p1} - F_{p2} = kF_{p1} \log_{10}(t_2/t_1) \quad (2)$$

Since  $v_1 \cdot t_1 = v_2 \cdot t_2$ , the above equation can be recast as:

$$F_{p2} = F_{p1} [1 - k \log_{10}(v_1/v_2)] \quad (3)$$

where  $t_1$  is the separation time at the separation speed  $v_1$ ,  $F_{p1}$  is the peeling force at the separation speed  $v_1$ ,  $t_2$  is the separation time at the separation speed  $v_2$ , and  $F_{p2}$  is the peeling force measured at the separation speed  $v_1$ .

Therefore, using the measured peeling force at a separation speed of 0.3 m/min, the peeling force at any other separation speed can be predicted using Eq. (3). It is obvious from Eq. (3) that the peeling force increases when the separation speed is increased. While the results of Tables III-VI show the peeling forces measured at very low speed compared to the real process speed, the effects of the forming belt mesh size, jet pressure, and web basis weight on the peeling force will not change with the separation speed.

TABLE VII. Length of fibers that are left caught in the knuckles of the forming belt after separating the forming belt from the fabric

Forming belt	Mean fiber length	Standard deviation of fiber length	Number of fibers measured
10 mesh	18.1 mm	8.8 mm	26
36 mesh	15.5 mm	9.4 mm	26
75 mesh	10.2 mm	4.3 mm	15
100 mesh	6.0 mm	1.2 mm	8

## CONCLUSIONS

This paper details experimental investigation of the peeling force required for separating the hydroentangled fabric from the forming belt. The peeling force is measured for fiberwebs with different basis weights formed with different jet pressure on different forming belts. It is found that for any given type of a forming belt, the peeling force increases with the increase of the jet pressure for a given basis weight of the fiberweb, and increases with the decrease of the fiberweb basis weight at a given jet pressure. It is also found that when the other process parameters are the same, the use of a coarser mesh forming belt leads to more fibers caught between the wires in the knuckles, hence a larger peeling force.

The magnified images of the forming belt show that after the fabric is separated from the forming belt, some fibers are left caught by the wires. For a coarser mesh forming belt, more fibers are left caught by the forming wires for a given jet pressure and fiberweb. When other processing conditions are the same, more fibers are left caught by the wires for the fiberweb with a smaller basis weight after the fabric is removed. It is concluded that the primary reason why a force is required to separate the fabric from the forming belt is fiber entrapment (fibers are entangled around the wires and pushed into the knuckles) by the forming wires. These fibers are held tightly by the forming wires and the entangled fiberweb and break during to the fabric separation from the forming belt thus generating the peeling force.

## ACKNOWLEDGEMENT

The support provided by the Nonwoven Cooperative Research Center of North Carolina State University is gratefully acknowledged. Helpful discussions with industry advisors of this project, C. Camelio, R. Holmes, F. Noëlle, Dr. D. Shiffler and C. B. Widen, are greatly appreciated.

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## **EXHIBIT B**

# SPUNLACE (HYDROENTANGLEMENT)

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(Hsu-Yeh Huang & Xiao Gao)

## 1. INTRODUCTION

The oldest technique for consolidating fibers in a web is mechanical bonding, which entangles the fibers to give strength to the web [1]. Under mechanical bonding, the two most widely used methods are needlepunching and spunlacing (hydroentanglement). Spunlacing uses high-speed jets of water to strike a web so that the fibers knot about one another. As a result, nonwoven fabrics made by this method have specific properties, as soft handle and drapability. Japan is the major producer of hydroentangled nonwovens in the world. The output of spunlaced fabrics containing cotton was 3,700 metric tons and a significant growth in production can still be seen [2]. The biggest producers of spunlaced fabrics in the U.S. are DuPont, Chicopee and Kendall corporations.

This technology was officially introduced by DuPont in 1973 (Sontara®) and is a result of considerable work done by DuPont and Chicopee (DuPont obtained five patents on spunlaced nonwovens within the period 1963-1970. Since the 1990's, the technology has been made more efficient and affordable for more manufacturers. Majorities of hydroentangled fabrics have incorporated dry-laid webs (carded or air-laid webs as precursors). This trend has changed very recently with an increase in wet-laid precursor webs. This is because of Dexter making use of Unicharm's technology to make spunlaced fabrics using wet-laid fabrics as precursors [3].

So far, there are many different specific terms for spunlaced nonwoven like jet entangled, water entangled, and hydroentangled or hydraulically needled. The term, spunlace, is used more popularly in the nonwoven industry. In fact, the spunlace process can be defined as: the spunlace process is a nonwovens manufacturing system that employs jets of water to entangle fibers and thereby provide fabric integrity. Softness, drape, conformability, and relatively high strength are the major characteristics that make spunlace nonwoven unique among nonwovens.

## 2. PROCESS

Spunlacing is a process [3,5] of entangling a web of loose fibers on a porous belt or moving perforated or patterned screen to form a sheet structure by subjecting the fibers to multiple rows of fine high-pressure jets of water (Fig. 1). Various steps are of importance in the hydroentangling process.

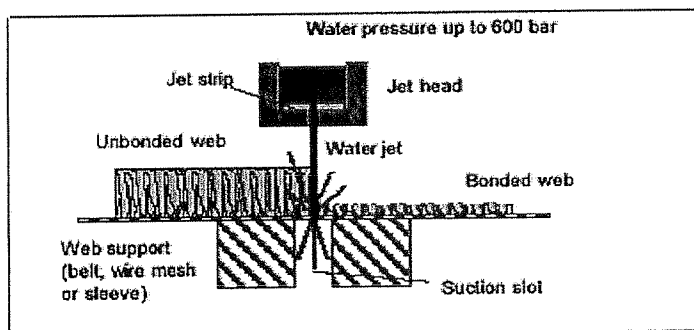


Fig. 1: Spunlace process [23]

While some of them are typical in a nonwoven process, some of them are unique to the process of spunlacing. The steps characteristic for producing hydroentangled nonwoven fabric include:

- Precursor web formation
- Web entanglement
- Water circulation
- Web drying

The formed web (usually air-laid or wet-laid, but sometimes spun bond or melt-blown, etc.) is first compacted and prewetted to eliminate air pockets and then water-needed. The water pressure generally increases from the first to the last injectors. Pressures as high as 2200 psi are used to direct the water jets onto the web. This pressure is sufficient for most nonwoven fibers, although higher pressures are used in specialized applications. It has been argued that 10 rows of injectors (five from each side of the fabric) should achieve complete fabric bonding [12]. Injector hole diameters range from 100-120  $\mu$  m and the holes are arranged in rows with 3-5 mm spacing, with one row containing 30-80 holes per 25 mm [3]. The impinging of the water jets on the web causes the entanglement of fibers. The jets exhaust most of the kinetic energy primarily in rearranging fibers within the web and, secondly, in rebounding against the substrates, dissipating energy to the fibers. A vacuum within the roll removes used water from the product, preventing flooding of the product and reduction in the effectiveness of the jets to move the fibers and cause entanglement (fig.2 a, b & c).

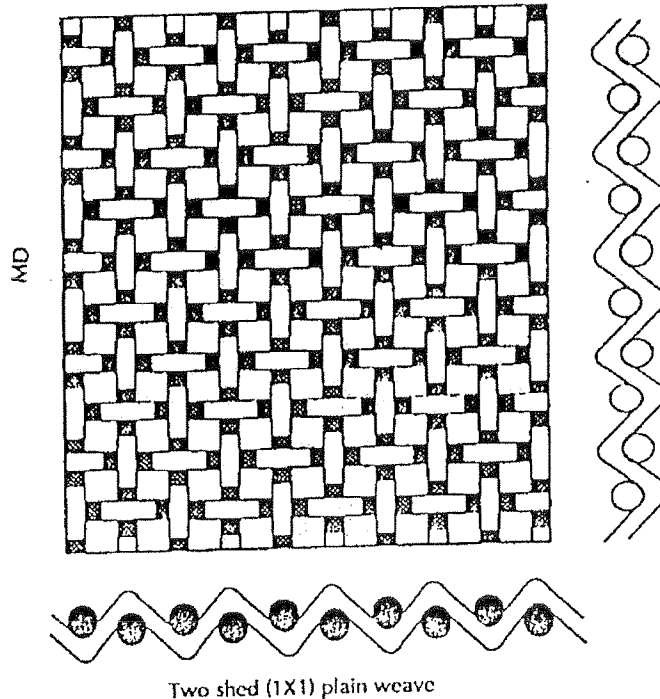


Fig. 2a: Spunlace support wire details

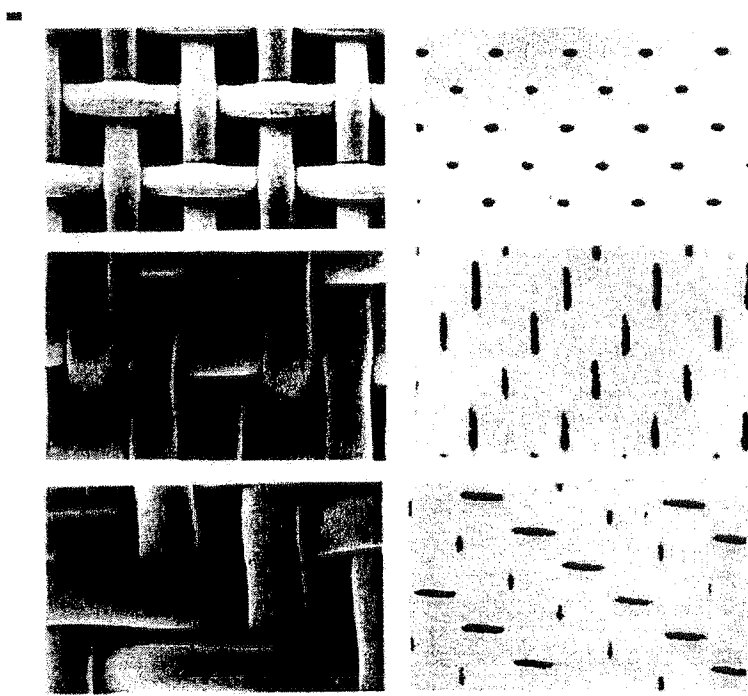


Fig. 2b: Spunlace support wire and the product

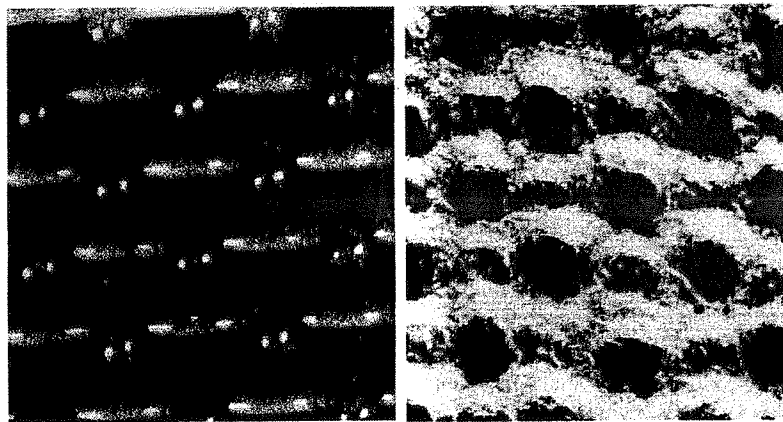


Fig. 2c: Spunlace support wire and the product enlarged

Usually, hydroentanglement is applied on both sides in a step-wise manner. As described in the literature [6], the first entanglement roll acts on the first side a number of times in order to impart to the web the desired amount of bonding and strength. The web then passes over a second entanglement roll in a reverse direction in order to treat and, thereby, consolidate the other side of the fabric. The hydroentangled product is then passed through a dewatering device where excess water is removed and the fabric is dried.

Hydroentanglement carried out at standard conditions (six manifolds of needles, 1500 psi, web weighing 68 g/m<sup>2</sup>) requires 800 pounds of water per pound of product [14]. For that reason it is necessary to develop a new filtration system able to effectively supply clean water with this high throughput; otherwise, water jet holes become clogged. This system consists of three stages: chemical mixing and

flocculation, dissolved air flotation and sand filtration [14]. Spunlaced fabrics have led to a lot of speculation regarding their manufacture because most of the manufacturing process details are considered as proprietary [4].

### 3. MATERIALS USED IN SPUNLACED TECHNOLOGY

As previously mentioned, hydroentanglement could be carried out using dry-laid (carded or air-laid) or wet-laid webs as a precursor. Most commonly, precursors are mixtures of cellulose and man-made fibers (PET, nylon, acrylics, Kevlar (P84, (imide) etc). In addition, Asahi Chemical Industry [3] has used very fine fibers produced from splittable composite fibers to produce hydroentangled substrates for synthetic suede leather products.

In general, cellulosic fibers are preferred for their high strength, pliability, plastic deformation resistance and water insolubility. Cellulosic fibers are hydrophilic, chemically stable and relatively colorless. Another advantage is that cellulose has an inherent bonding ability caused by a high content of hydroxyl groups, which attract water molecules. As the water evaporates from the fabric, the hydroxyl groups on fiber surface link together by hydrogen bonds.

Influence of cotton micronaire on fabric properties has been studied [14]. Generally, low micronaire cotton is not recommended for hydroentangled nonwovens because of higher number of neps and small bundles of entangled fibers, resulting in unsightly appearing fabric. In spite of this, fabrics made with lower micronaire fiber show higher strength, probably caused by a higher number of fine fibers and greater surface area.

In addition, greige cotton has been used in spunlacing technology. It has been shown that the absorbency rate increases with increasing hydroentangling energy. This is the result of oil and wax removal from the fiber surface. These nonwovens can be subsequently bleached, which should raise the strength of the fabric [14].

We can summarize all the processes that can be separated into following categories: [15-19]

#### 3.1 THE CHOICE OF FIBERS

The fiber used in spunlaced nonwoven should think about following fiber characteristics.

- Modulus: Fibers with low bending modulus requires less entangling energy than those with high bending modulus.
- Fineness: For a given polymer type, larger diameter fibers are more difficult to entangle than smaller diameter fibers because of their greater bending rigidity. For PET, 1.25 to 1.5 deniers appear to be optimum.
- Cross section: For a given polymer type and fiber denier, a triangular shaped fiber will have 1.4 times the bending stiffness of a round fiber. An extremely flat, oval or elliptical shaped fiber could have only 0.1 times the bending stiffness of a round fiber.
- Length: Shorter fibers are more mobile and produce more entanglement points than longer fibers. Fabric strength, however, is proportional to fiber length; therefore, fiber length must be selected to give the best balance between the number of entanglement points and fabric strength. For PET, the fiber length from 1.8 to 2.4 seems to be best.

- Crimp: Crimp is required in staple fiber processing systems and contributes to fabric bulk. Too much crimp can result in lower fabric strength and entanglement.
- Fiber wettability: Hydrophilic fibers entangle more easily than hydrophobic fibers because of the higher drag forces.

### 3.2 PRECURSOR WEB FORMATION

Theoretically, any nonwoven web forming process can be used in the spunlace process. It depends on what kind of products you desire. The general properties of web forming from other process are listed as following:

- Isotropic precursor webs can be produced by air laying system.
- Carding webs can result in final products, which have higher MD strength than CD strength.
- Melt blown webs can be produced with good 'squareness' of the web. Wet formed webs can especially be produced with good machine direction / cross direction characteristics.
- The combinations of various types of precursor webs provide numerous options for using in the spunlace process to create various different composites.

### 3.3 WEB SUPPORT SYSTEM (CONVEYOR WIRE)

The web support system plays an important part in most nonwoven processes. Especially for the spunlace process, it has a critical role in this process because the pattern of the final fabric is a direct function of the conveyor wire. By special design for the wire, we can have following varied products:

- Ribbed and terry cloth-like products
- Aperture products
- Lace patterns or company logo can be entangled into fabrics
- Production of composites
- 3-D fabric formation

There are two general characteristic wires in spunlace system. The comparison of their properties is listed in Table 1.

Table 1: Comparison of metal and plastic wires

Plastic wire	Metal wire
Good flex resistance	Poor flex resistance
Light weight	Heavy weight
Easy to install	Difficult to install
Corrosion resistant	Prone to corrosion
Difficult seams	Invisible seam
Prone to shower damage	Shower damage resistance
Difficult to control knuckle height	Easier to control knuckle height
Moderate temperature	High temperature

In fact, the surface characteristics of the forming wire determine what the nonwoven products will look like. A smooth top surface of forming wire is desired for little or no marking. As for the aperture product, there is a high knuckle in the forming wire. A high knuckle in the wire will give a large hole in the fabric since the high-pressure water jets are deflected by the high knuckle.

### 3.4 THE ENTANGLEMENT UNIT

Hydroentanglement is an energy transfer process where the system provides high energy to water jets and then transfers the energy to the precursor. In other words, the energy is delivered to the web by the water needles produced by the injector. Therefore, we can calculate the energy from the combination of the water velocity (related to the water pressure) and the water flow rate (related to the diameter of the needles).

$$\text{Flow rate} = P^{1/2} \times D^2 \times N \times 2572 \times 10^{-8} \text{ m}^3/\text{hour/injector/meter}$$

$$\text{Energy} = P^{3/2} \times D^2 \times N \times 7 \times 10^{-10} \text{ KWH/injector/meter}$$

P= water pressure (bar)

D=hole diameter (  $\mu$  m )

N= number of holes (per injector per meter)

In general, the diameter of water needle ranges from 100 to 170  $\mu$  m. The highest number of needles is 1666 needles per meter of injector, corresponding to the smaller diameter. The water pressure ranges from 30 bars to 250 bars and it is increased stepwise from injector to injector.

### 3.5 WATER SYSTEM

As we know, water is most critical part in spunlace process. Therefore, there are some requirements for the water as follows:

- Large amount of water – about  $606 \text{ m}^3/\text{hr}/\text{m}/\text{injector}$  for 40 bar and 120° m
- Nearly neutral pH
- Low in metallic ions such as Ca
- No bacteria or other organic materials

### 3.6 FILTRATION SYSTEM

Due to the large amount of water consumed, the spunlace process requires that it be recycled. Therefore, a high quality filtration system is necessary for the spunlace process. Some of special filters are listed as following:

- Bag filter
- Cartridge filter
- Sand filter

### 3.7 WEB DRYING

When the fabric leaves the entanglement zone the web, it is completely saturated with water. There are a few steps to remove water from the fabric. The include:

- Vacuum dewatering system
- Drying system

## 4. PARAMETER AFFECTING THE PRODUCT PERFORMANCE PROPERTIES

Both the fiber and web properties have primary effects on the performance of the finished product. These parameters comprise of the web material and area basis-weight, and the way in which the web was manufactured. As mentioned in literature [12], spunlaced technology demands a high quality web, especially in its uniformity and isotropic orientation.

The process variables are considered to have secondary effects on the performance of the finished product. The supporting substrate transport is an important variable influencing the fabric. There are two systems of entanglement substrate systems: flat and rotary. For the most part [6], there is no difference in the mechanism used to achieve entanglement. The rotary concept uses a compact machine design with ease of sheet run that provides entanglement of both sides of the web. Entanglement is nearly achieved with as little as four meters (in the machine direction) of the material. Sometimes the fibers are driven through the substrate wire and, in the flat concept, it is seen that the wire (along with the fibers) is dragged over the suction box causing difficulty in the removal of the product. In the rotary concept, this problem is not encountered because the fibers are not pulled along the machine direction.

The substrate texture seems to have important influence on the product. The size of perforations is usually measured in "mesh", which is the count of wires per inch of the substrate. It has been shown [6] that imposing the same energy into two webs with different substrate meshes, the finer substrate yielded a stronger product resulting from finer support. The coarser wire support (20 mesh) gave a bulkier product with more permeability, but with less strength. Water removal from the fabric was shown to be dependent on the mesh of the support belt. The lower the mesh, the more energy that was necessary to remove the remaining water. In addition to that, the surface of the fabric can be aperture (textured on the surface) with a specially structured substrate [13].

The amount of energy delivered in the web is a crucial parameter influencing the fabric structure and properties since it affects fiber entanglement completeness. "Completeness" is a term that is defined [6] as "the portion of fibers that are tied together". DuPont patent literature has methods for entanglement completeness testing. Water pressure is another parameter related to fabric energy intake. There are several water pressure levels used (see Table-2)[12].

Now, higher water pressure machines are mostly used since using high pressure, energy can be delivered into a web with less water needles and less water. This is economically more useful [12].

Another basic process parameter having influence on the fabric is the speed of the line. If a constant amount of energy is being delivered to a fabric, the speed of the fabric determines how much energy is going to be absorbed per fabric unit area. Logically, the higher the line speeds, the less the energy that is absorbed by the fabric and the lower the fabric strength that is achieved.

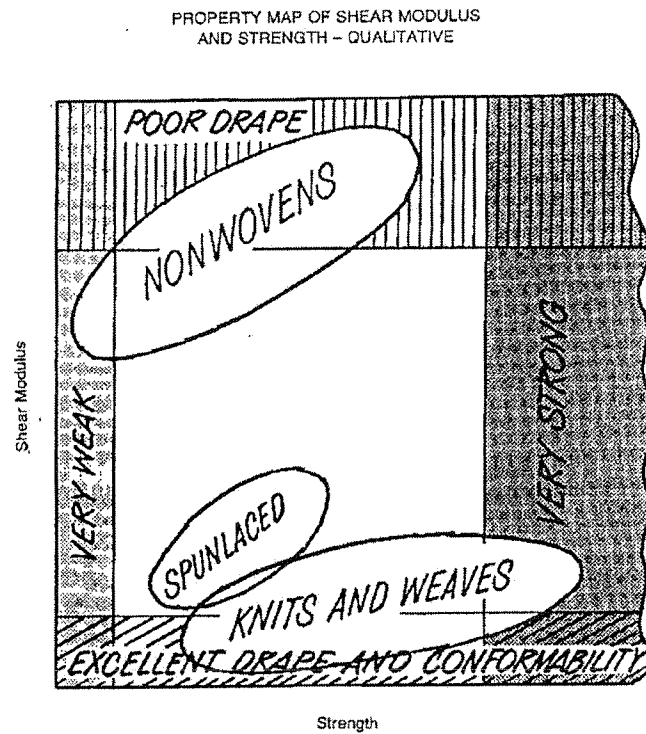
## 5. PROPERTIES OF SPUNLACED FABRICS

Spunlaced fabrics show high drape, softness and comfortable handle because more fiber entanglement leads to increased strength without an increase in shear modulus. It has also been shown that there is a relationship between absorbency capacity and hydroentangling energy used. An increase of hydroentangling energy results in a decrease of absorbency capacity and absorbency rate [14]. Shear modulus remains low and is virtually independent of the degree of entanglement [7]. The softness of the fabric is explained by the fact that the entangled structures are more compressible than bonded ones, as well as having mobility and partial alignment of fibers in the thickness direction. The absence of a binder is seen to result in a fabric with yarn-like fabric intersections composed of "pseudoyarns". The pseudoyarns are "more highly intereconnected than yarns of conventional fabrics because individual fibers can migrate from one pseudoyarn to another. This tends to stabilize the intersection". This pseudoyarn structure seems to be the reason for good dimensional stability, which is also accountable for drape [4], softness, and good strength/weight properties of the fabric, pilling and abrasion behavior.

The strength of hydroentangled fabrics is lower than that of woven and higher than that of knitted fabrics, whereas the wash durability is considerably lower than that of woven or knitted fabrics [11].

## 6. THE INFLUENCE OF PROPERTIES OF FABRIC ON THE SPUNLACE PROCESS [20]

Spunlaced fabrics are unique among nonwoven fabrics because of the balance achieved between strength and shear modulus. General speaking, spunlaced fabrics rely primarily on fiber-to-fiber friction to achieve physical integrity and are characterized by relatively high strength, softness, drape, conformability and aesthetics closely approaching woven and knitted fabrics. The property map of shear modulus and strength is listed in Fig-4 below



Therefore, the operational condition change in the process will affect directly on the properties of fabrics. For example Fig-5, show that the spunlaced fabric has the lowest shear modulus among the nonwoven fabrics and is very close to the shear modulus of woven and knitted fabric. Even if one tries to increase the fabric strength, it doesn't increase the shear modulus, as is the case normally for other nonwoven fabrics.

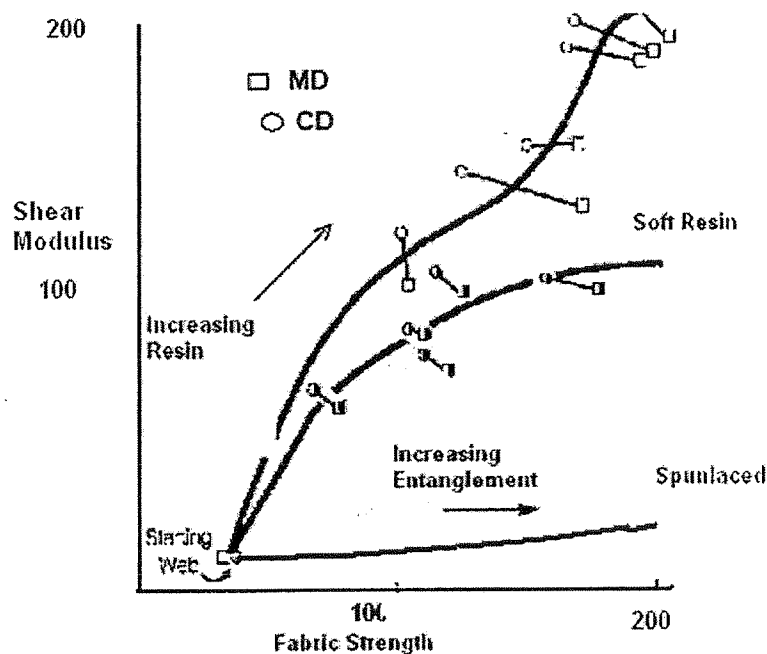


Fig. 5: Fabric strength and Modulus

Fig. 6 shows that the tensile strength of fabric increases with water pressure increase. This is due to the high energy from water imparted to the fiber entanglement.

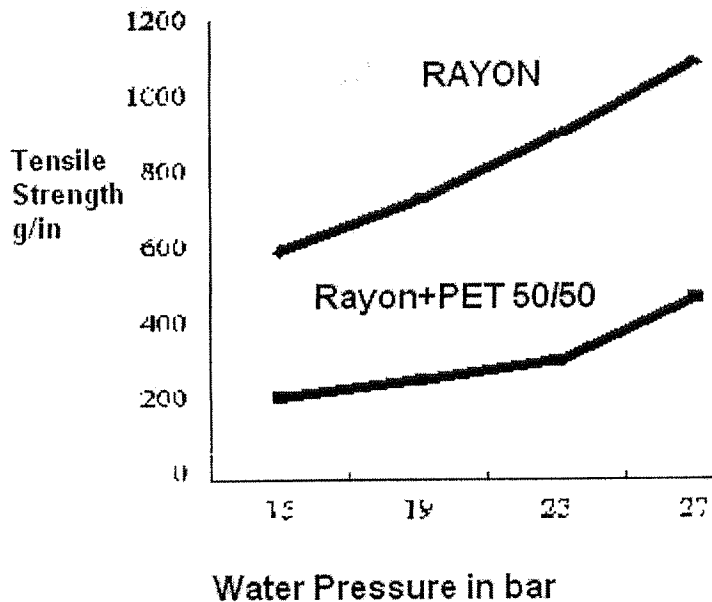


Fig. 6: Fabric strength verses water pressure

Generally, the water jet is perpendicular to the fabric. If we change the angle a little, the results show the strength increases as demonstrated in fig. 7. Additionally fig. 8 shows speeding the speed of conveyor will decrease the strength of fabric.

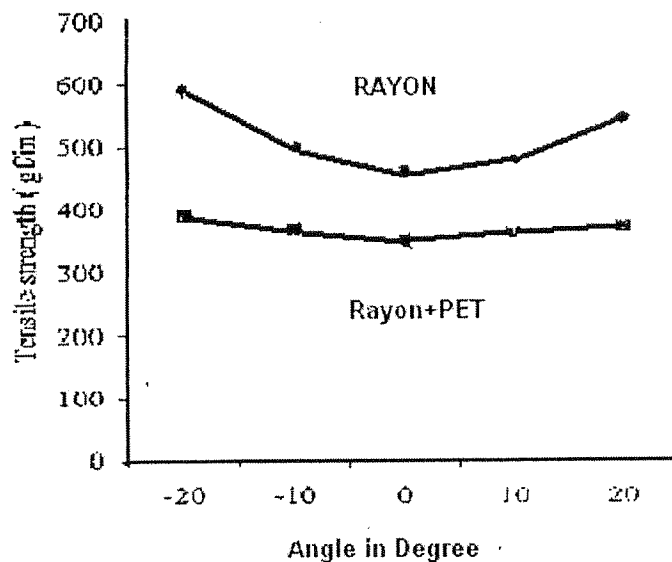


Fig. 7: Fabric strength verses jet angle

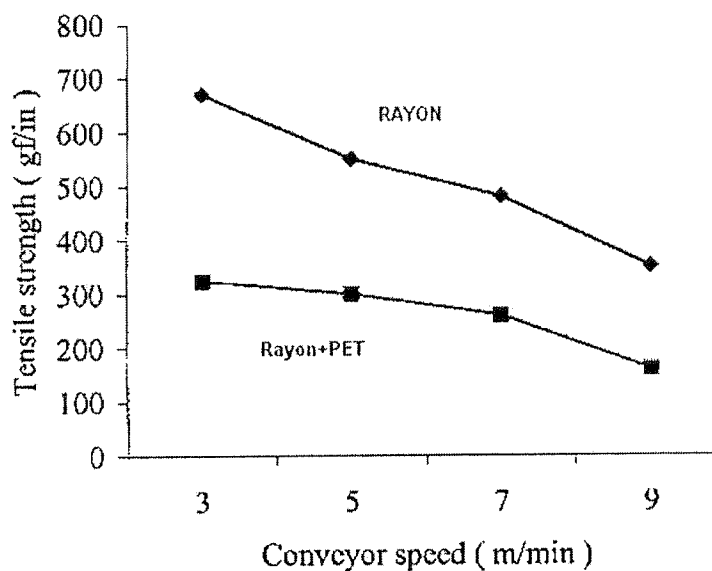


Fig. 8: Fabric strength verses conveyor speed

In the spunlace process, there are three water jet manifolds at least and the water pressure can be adjusted individually. Therefore fig 9,10, and11 illustrate the change of water pressure at each of the jet manifolds 1, 2 &3.

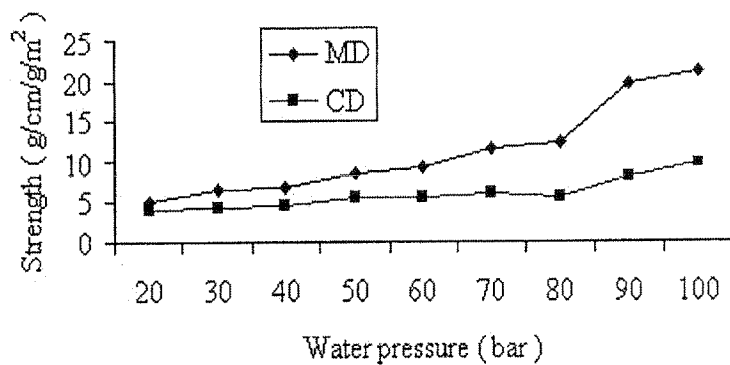


Fig. 9: Fabric strength verses water pressure in 1st manifold

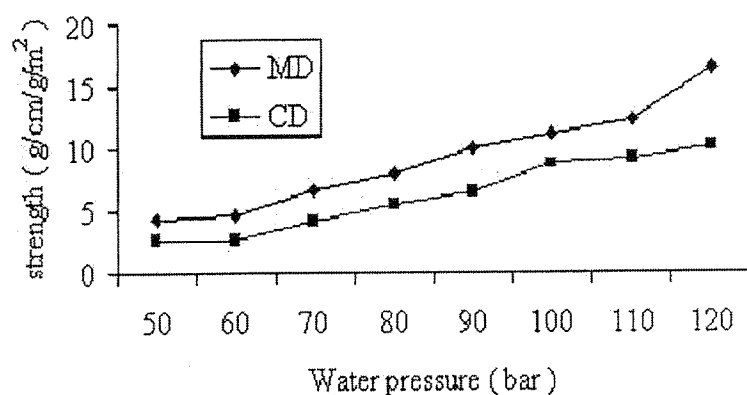


Fig. 10: Fabric strength versus water pressure in 2nd manifold

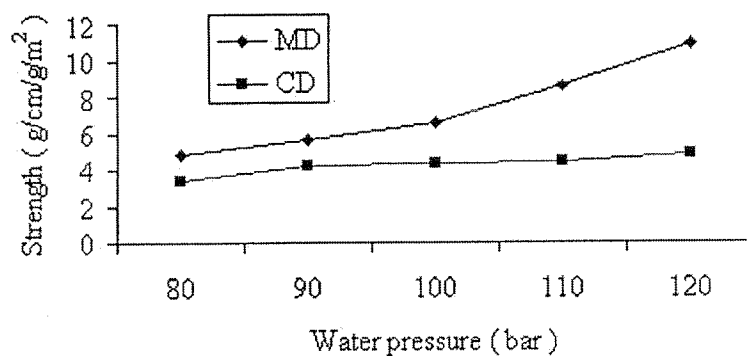


Fig. 11: Fabric strength versus water pressure in 3rd manifold

The results show the strength always increases with increasing water pressure. However, the lower water pressure at the first jet manifold and similar water pressure at second and third, the closer tensile strength for both MD and CD directions. In other words, the fabric is closer to isotropic properties as shown in Table 2. This is a very important factor in deciding what kind of material property will result.

Table 2.

Injector I (bar)	II (bar)	III (bar)	MD: CD
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20	70	100	1.27
30	70	100	1.55
40	70	100	1.51
50	70	100	1.50
60	70	100	1.67
70	70	100	1.93
80	70	100	2.19
90	70	100	2.47
100	70	100	2.23
30	50	100	1.71
30	60	100	1.82
30	70	100	1.55
30	80	100	1.43
30	90	100	1.54
30	100	100	1.29
30	110	100	1.33
30	120	100	1.60
30	70	80	1.33
30	70	90	1.39
30	70	100	1.55
30	70	110	1.95
30	70	120	2.25

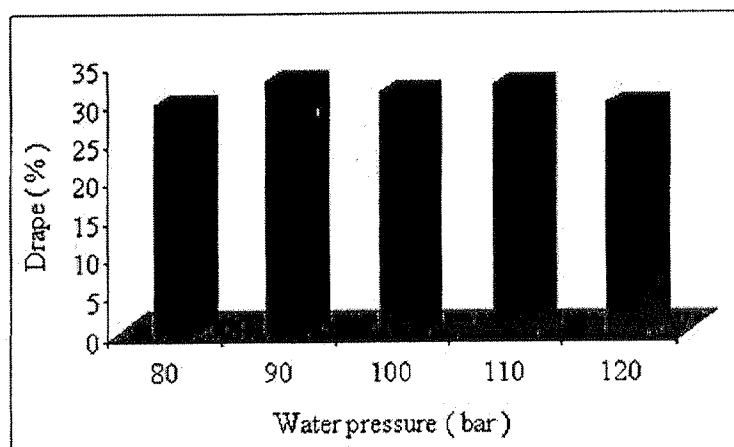


Fig. 12: Water pressure verses drape

Fig. 12 shows that there is no significant change for the drape with increasing water pressure which shows that spunlaced fabrics have good drape even with greater entangling pressure.

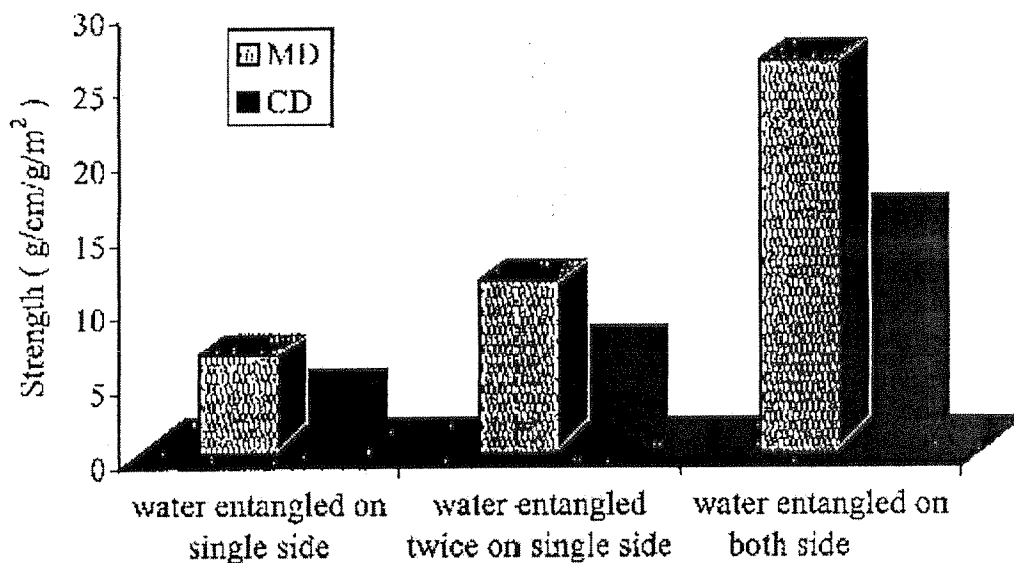


Fig. 13: Strength increases when entangled on both sides.

Fig13 shows that the tensile strength of water jet entangling on both sides is much better than that on a single or multiple treatments on one side.

## 7. APPLICATIONS

Hydroentanglement is a highly versatile process [8] because it can be used to produce nonwovens with a

broad range of end-use properties. These differences are achieved because of a wide range of fibers that are available and because of the broad range of possible parameter adjustments. The versatility of the hydroentanglement processes is seen as an advantage because this process can be used to combine conventionally formed webs with melt blown, spunbond webs, paper, other textiles and scrims in order to get a combination of properties that cannot be achieved by the use of a single web.

Spunlace fabrics can be further finished, usually dyed and/or printed, treated with binders to allow for wash durability, or fire retardants can be applied to resist burning. The fabric can be treated by antimicrobial agents to enhance resistance against microorganisms.

The largest US market [9] for spunlaced fabrics spans from surgical packs and gowns, protective clothing as chemical barriers to wipes, towels and sponges for industrial, medical, food service and consumer applications. The main reason for wide use of these fabrics in medical applications is based on relatively high absorption abilities. Another important criterion is absence of a binder in the fabric allowing sterilization of the fabric at high temperatures.

There are some applications: [22]

#### 1. Bacteria-proof Cloth (Fig. 14)

- Based on 100% Rayon. The extreme absorption with water and oily stuff are good for your convenience.
- For our unique green earth, we adopt the recyclable material for protecting the environment.
- By special water-processed method, the fluffed cotton cannot easily float away
- Easy to wash, quick dry, making a bacteriaproof environment.
- No Starch, No fluorescence substance, and other chemical medicines.



Fig. 14: Bacteria proof cloth

#### 2. Cleaning Cloth (Fig 15)

- Based on 100% Rayon. The extreme absorption with water and oily stuff provides convenience.
- For our unique green earth, we adopt the recyclable material for protecting the environment.

- By special water-processed method, the fluffed cotton cannot easily float away.
- Easy to wash, quick dry, resulting in a bacteria-proof environment.
- No Starch, No fluorescence substance, and other chemical medicine.

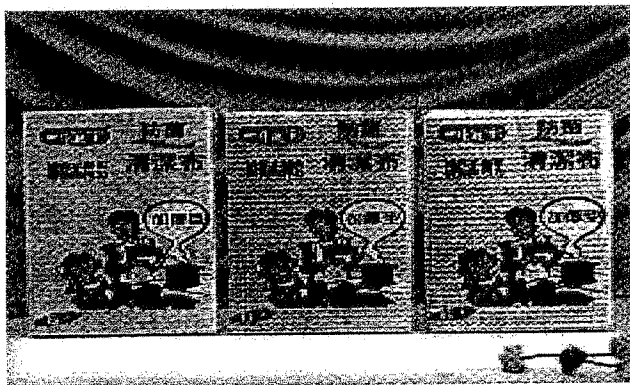


Fig. 15: Cleaning cloth

### 3. Magic Towel (Fig 16)

- Processed by the advanced high-pressure-water method, the magic towel has extreme absorption for water, oil stuff and so on. Definitely, it has no formaldehyde and gluey substances. That's good for your health and convenience.
- Easy to carry out for picnic, travel, and even as promotion gifts. One can print their LOGO on the tag for advertisement.

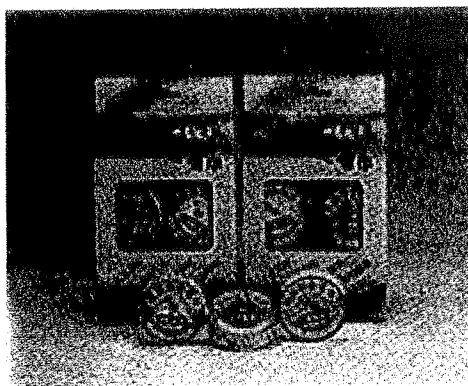


Fig. 16: Magic towel

### 4. Wet Tissue (Fig 17)

- Processed by the advanced high-pressure-water method. The nonwoven spunlace has no Formaldehyde.
- No glue-like substance, tender the soft skin.

- For the refreshing experience, it is comfortable for body and parents like it.
- The wet tissue is used for make-up, make-up removal, and other facial applications. In fact, it is convenient all the day.



Fig. 17: Wet tissues

#### 5. Make -up Cotton (Fig 18)

- Hi-Tech Nonwoven Spunlace which has no any chemical substance, but does have a soft touch and is tender to baby skin.
- Saving the lotion and make-up cream. Best absorption, No fluffed cotton.
- Best use for make up, wiping lips-sticker, fingernail polish, glasses, leather, jewels, and so on.

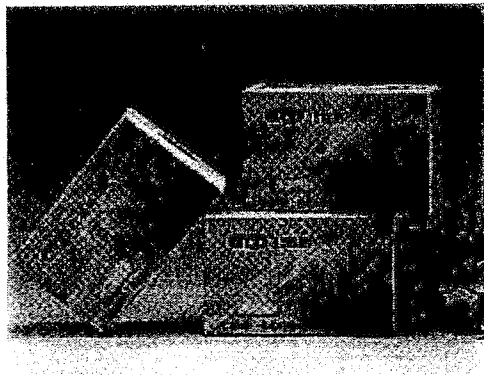


Fig. 18: Make up cotton

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US005136761A

**United States Patent** [19]

Sternlieb et al.

[11] **Patent Number:** 5,136,761[45] **Date of Patent:** Aug. 11, 1992[54] **APPARATUS AND METHOD FOR HYDROENHANCING FABRIC**[75] Inventors: **Herschel Sternlieb**, Brunswick, Me.;  
**Jodie M. Siegel**, Somerville, Mass.;  
**John M. Greenway**, Westwood, Mass.;  
**Zoltan Mate**, Sherborn, Mass.;  
**Frank E. Malaney**, Milton, Mass.[73] Assignee: **International Paper Company**,  
Purchase, N.Y.[21] Appl. No.: **608,933**[22] Filed: **Nov. 5, 1990****Related U.S. Application Data**

[63] Continuation-in-part of Ser. No. 382,160, May 18, 1989, Pat. No. 4,967,456, and a continuation-in-part of Ser. No. 184,350, Apr. 21, 1988, abandoned, and a continuation-in-part of Ser. No. 41,542, Apr. 23, 1987, abandoned.

[51] Int. Cl.<sup>5</sup> ..... **D04H 1/46**[52] U.S. Cl. .... **28/104; 8/151.2;**  
28/167; 68/205 R; 428/225[58] Field of Search ..... 28/104, 167; 8/151.2;  
68/205 R; 428/225[56] **References Cited****U.S. PATENT DOCUMENTS**

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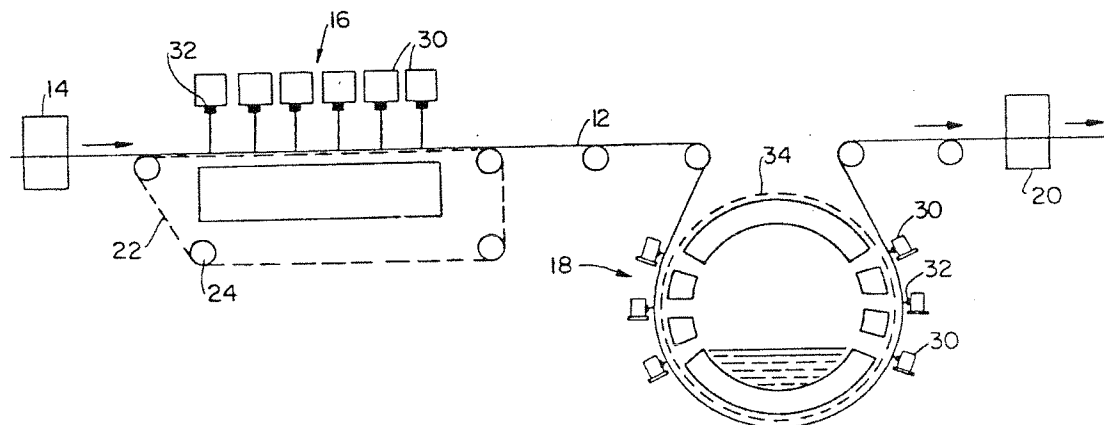
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*Primary Examiner*—Philip R. Coe*Attorney, Agent, or Firm*—Walt Thomas Zielinski[57] **ABSTRACT**

An apparatus 10 and related process for enhancement of woven and knit fabrics through use of dynamic fluids which entangle and bloom fabric yarns. A two stage enhancement process is employed in which top and bottom sides of the fabric are respectively supported on members 22, 34 and impacted with a fluid curtain including high pressure jet streams. Controlled process energies and use of support members 22, 34 having open areas 26, 36 which are aligned in offset relation to the process line produces fabrics having a uniform finish and improved characteristics including, edge fray, drape, stability, abrasion resistance, fabric weight and thickness.

**26 Claims, 22 Drawing Sheets**10

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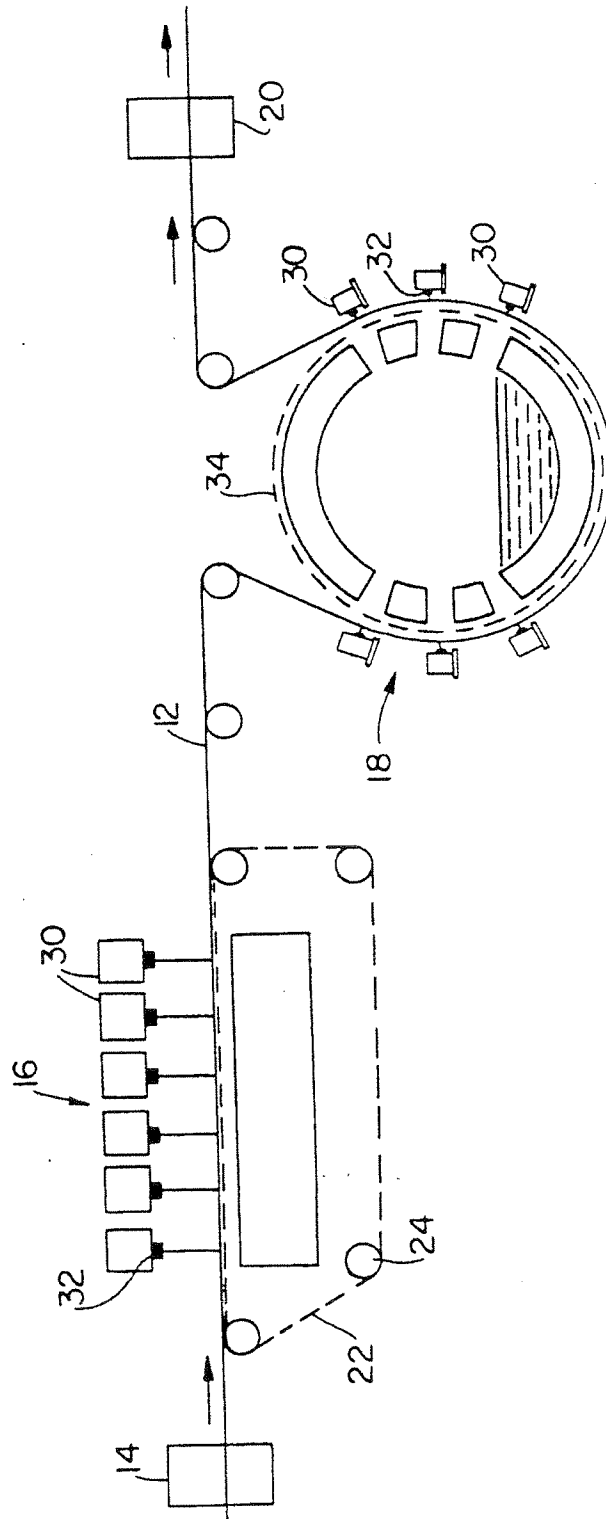


FIG. 1

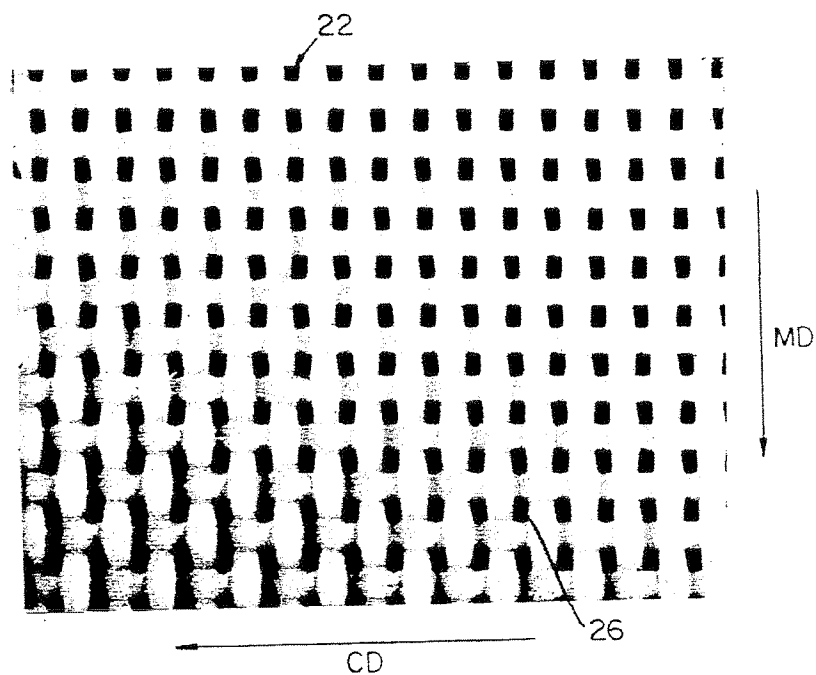


FIG. 2A

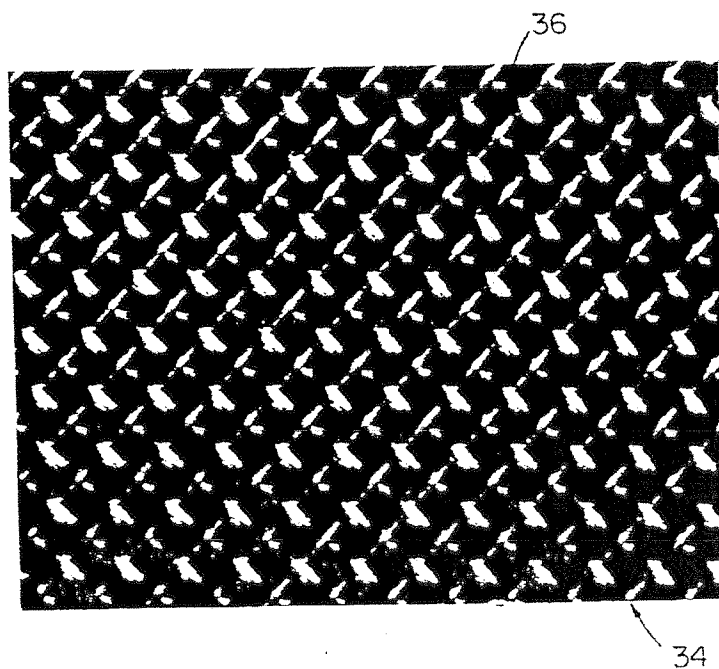


FIG. 2B

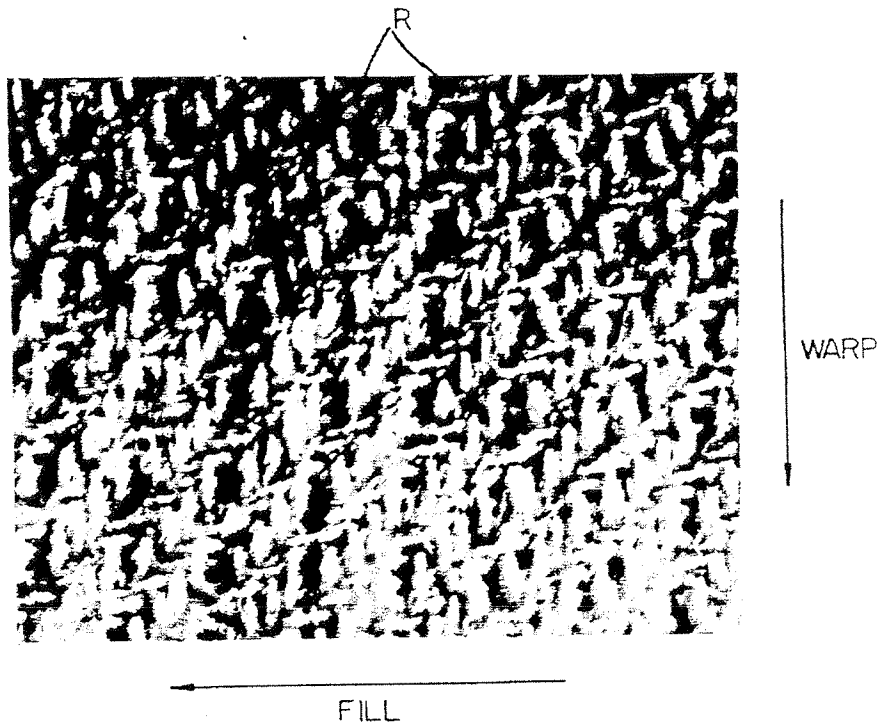


FIG. 3A

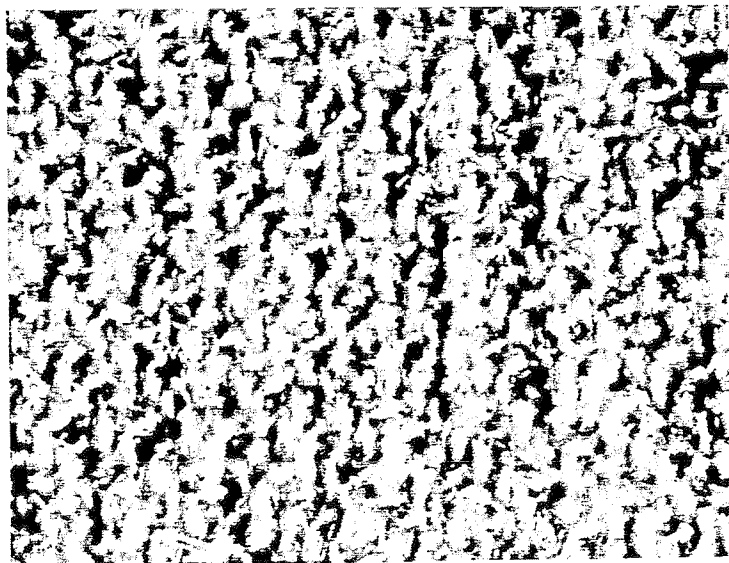


FIG. 3B

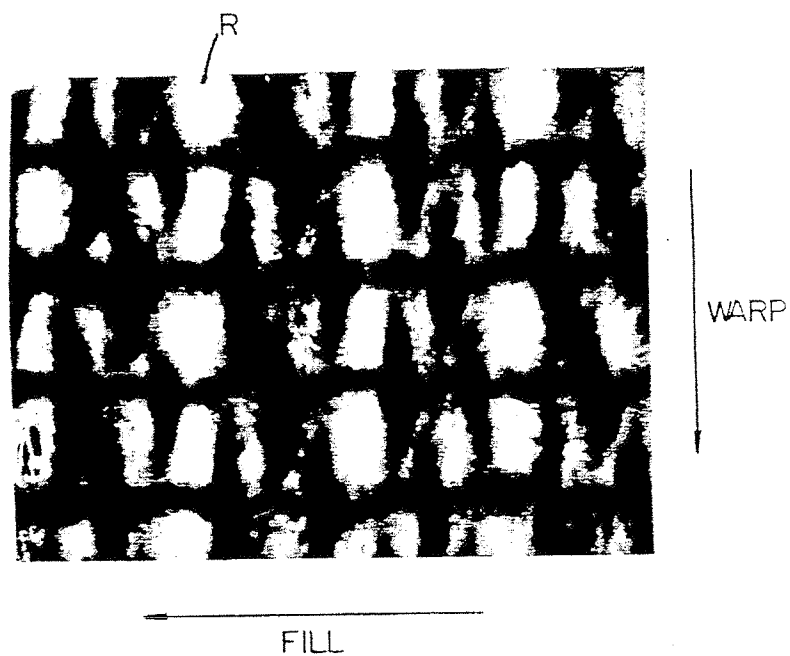


FIG. 4A

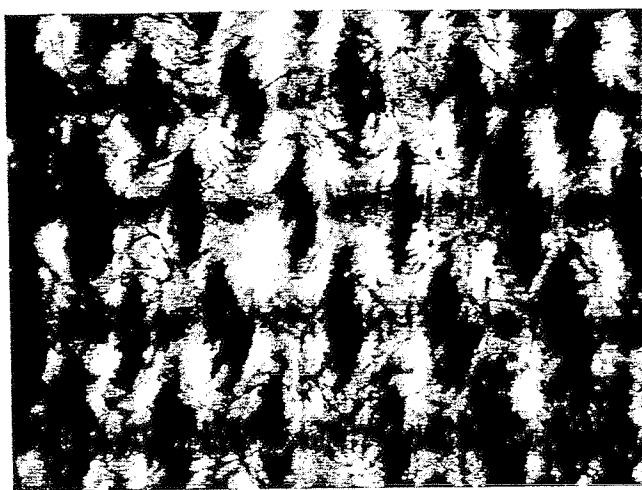


FIG. 4B

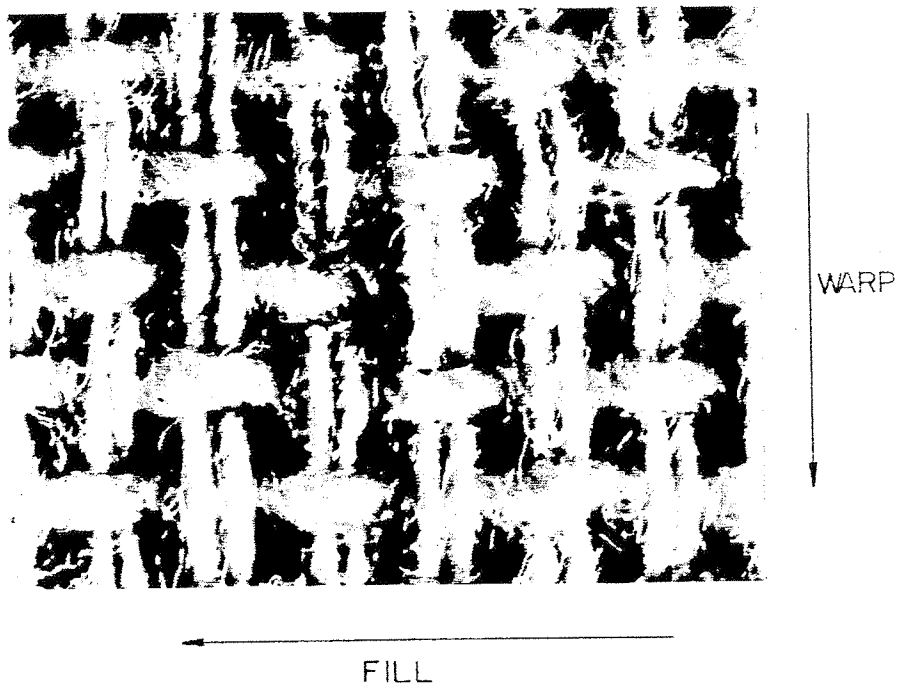


FIG. 5A

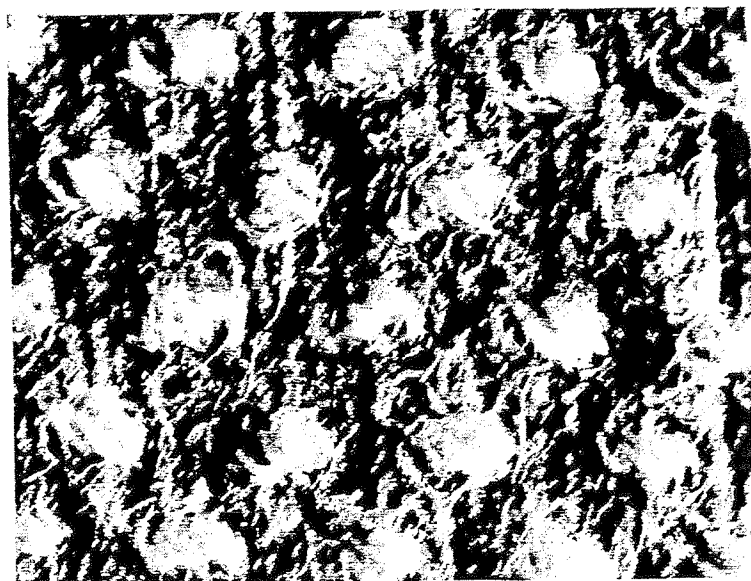


FIG. 5B

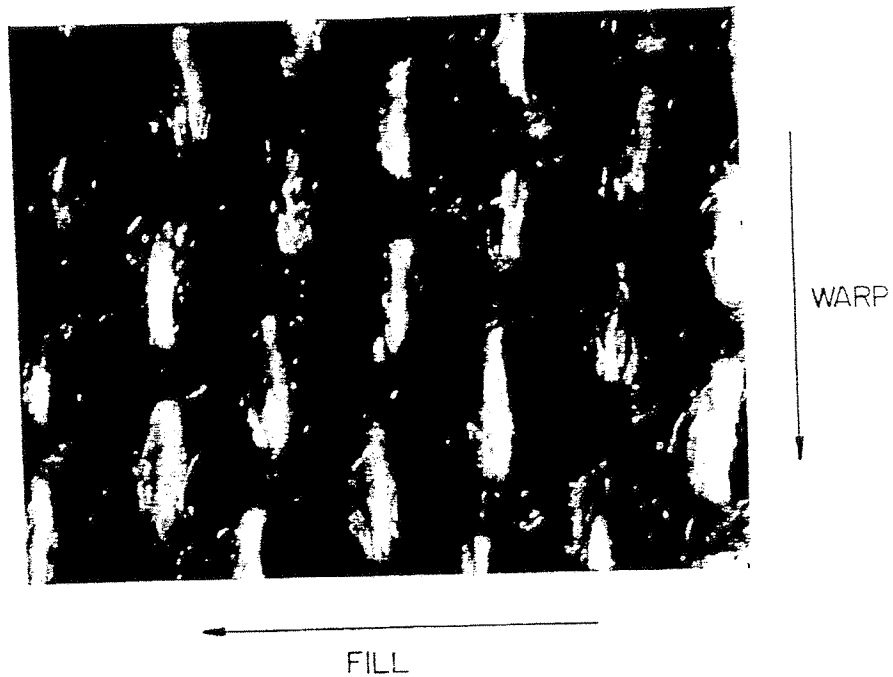


FIG. 6A

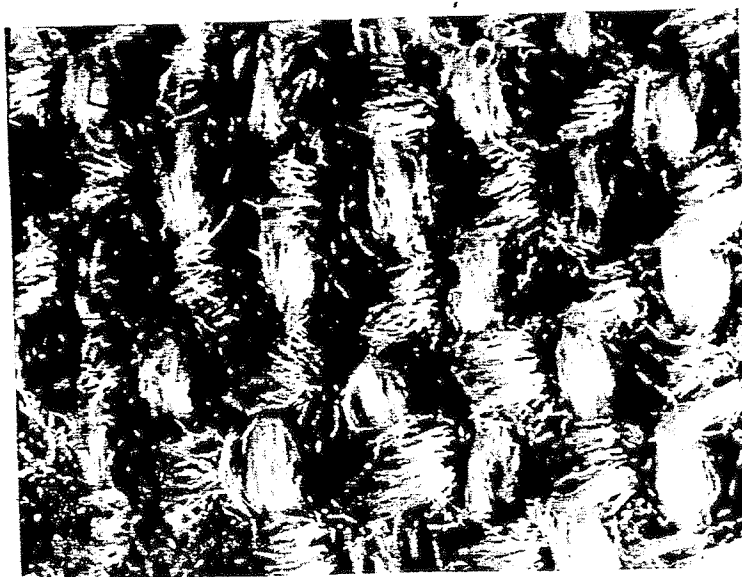
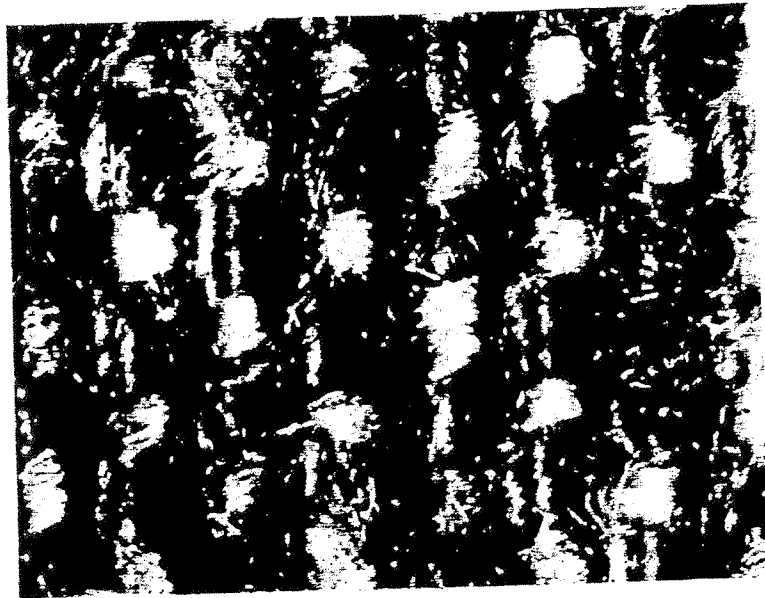


FIG. 6B



WARP

FILL

FIG. 7A

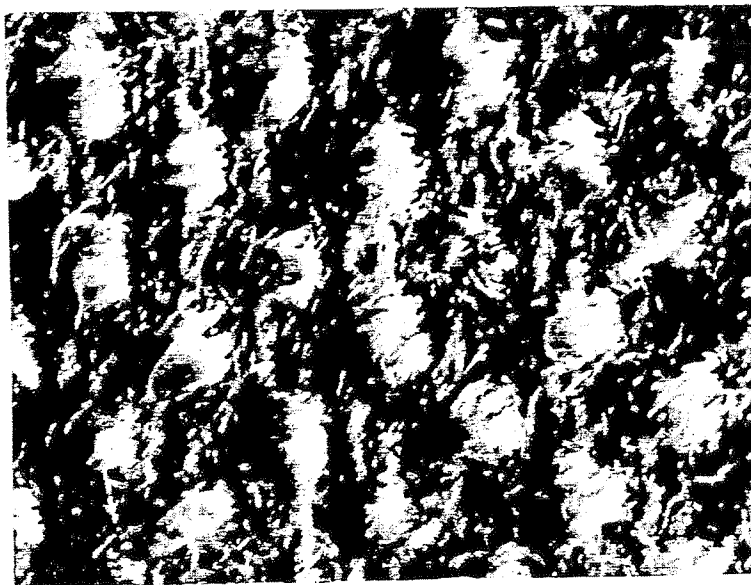


FIG. 7B

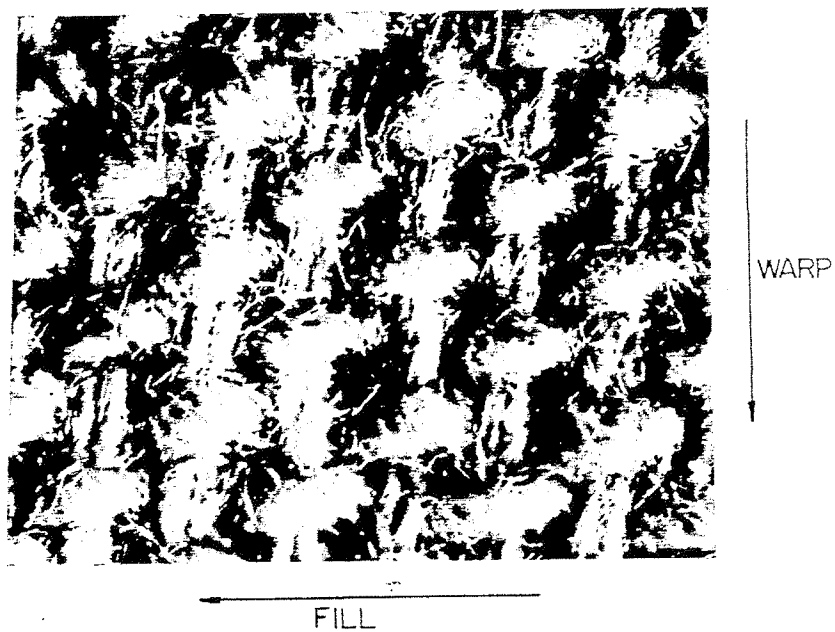


FIG. 8A

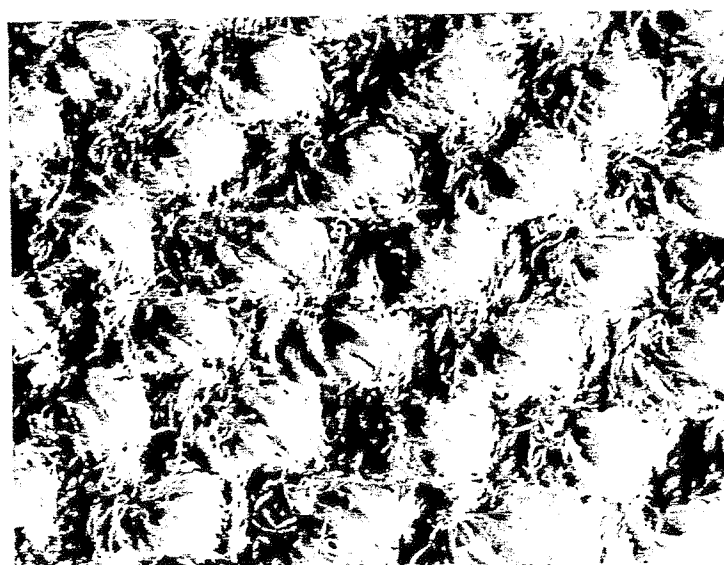
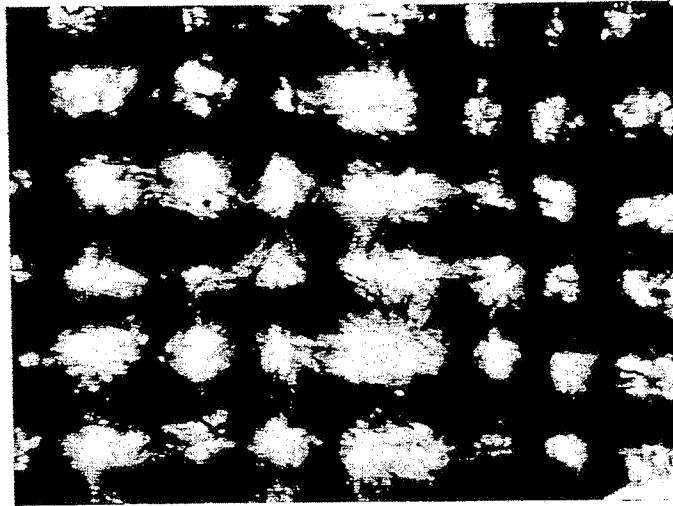


FIG. 8B



WARP

FILL

FIG. 9A

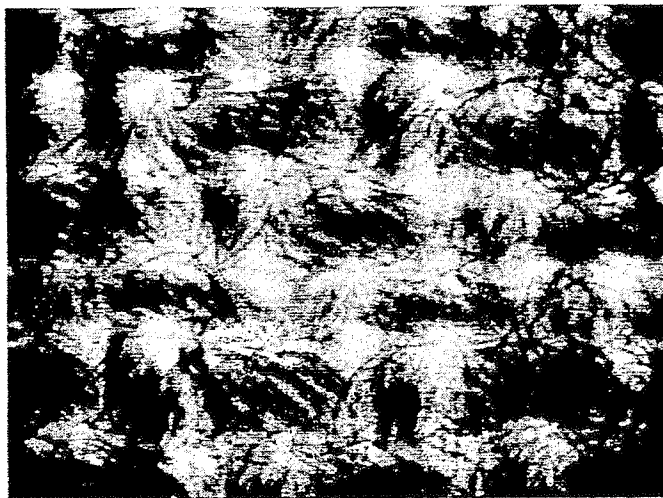
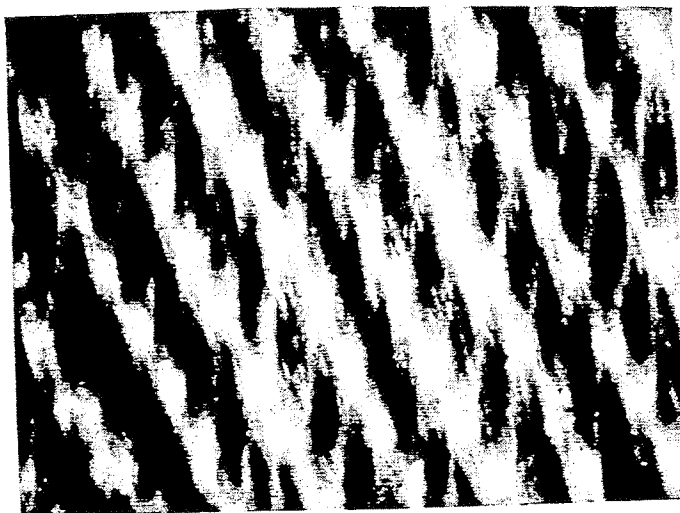


FIG. 9B



WARP

FILL

FIG. 10A

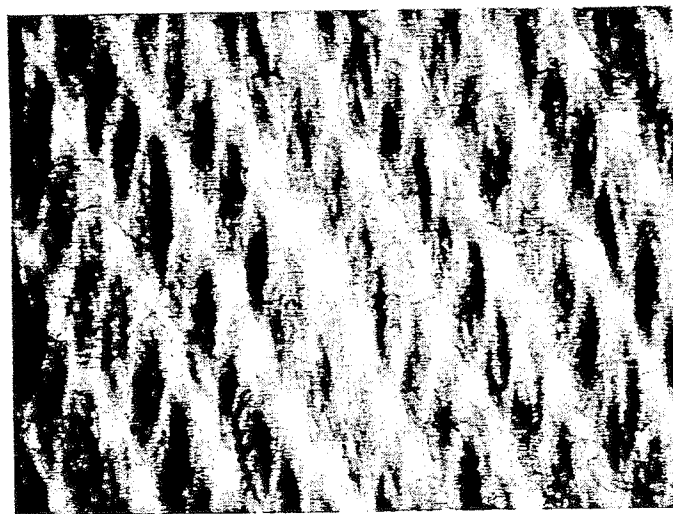
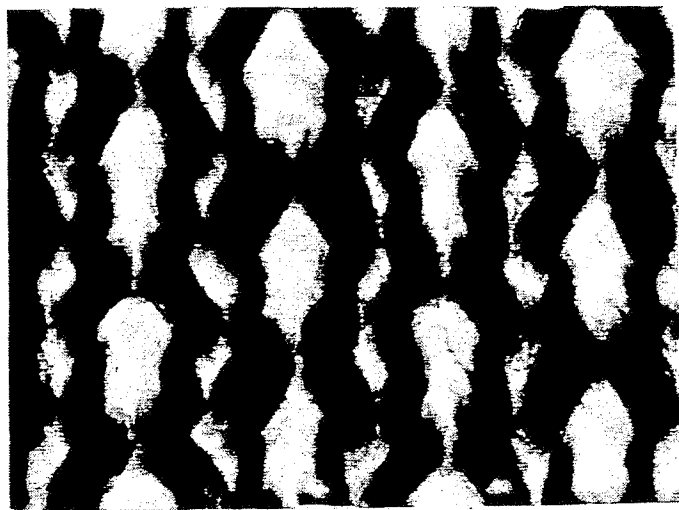


FIG. 10B



WALE

COURSE

FIG. IIA

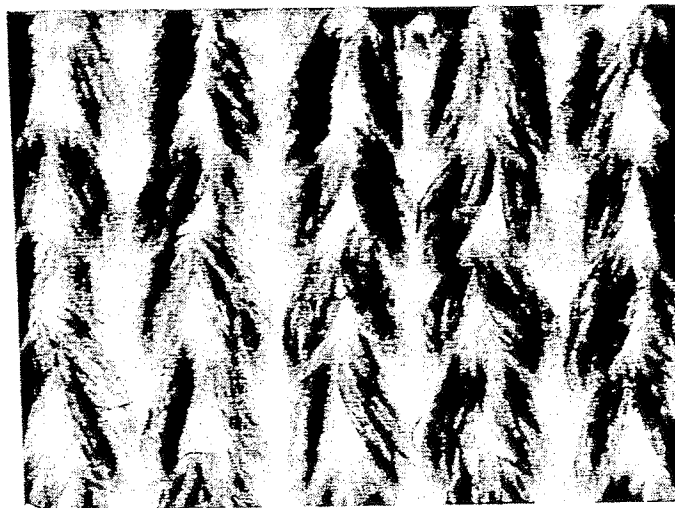


FIG. IIB

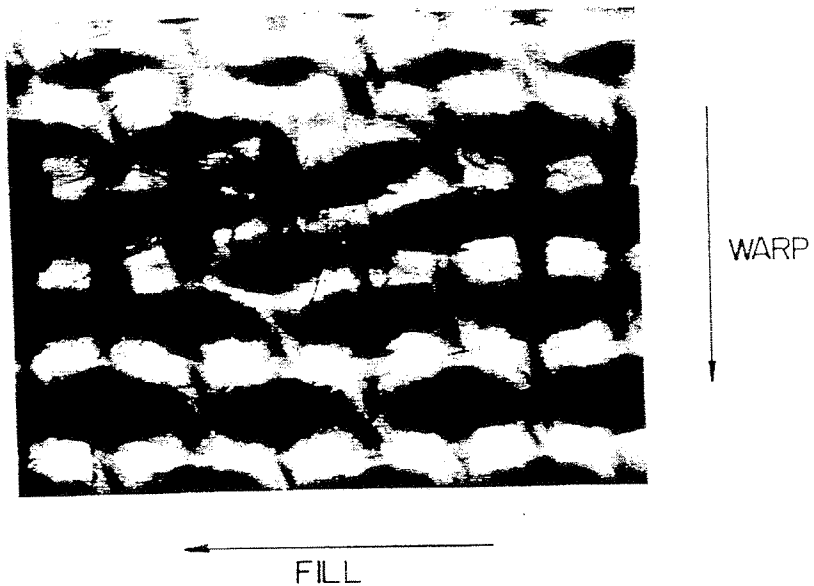


FIG. 12A



FIG. 12B



WARP

FILL

FIG. 13A

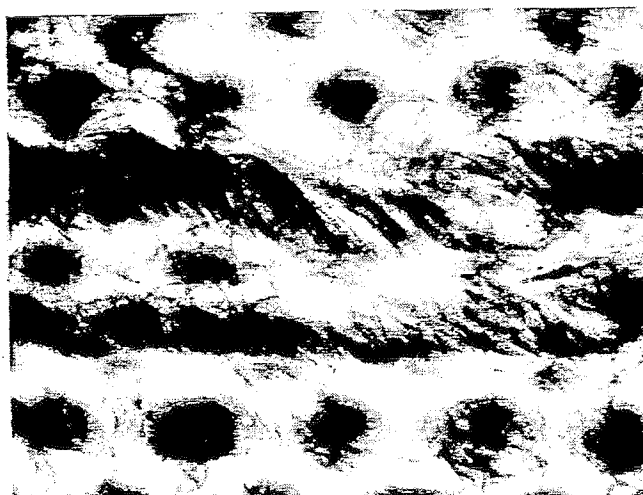


FIG. 13B

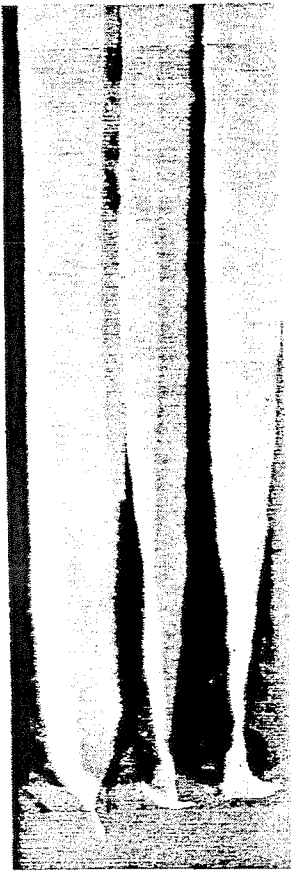


FIG. 14A

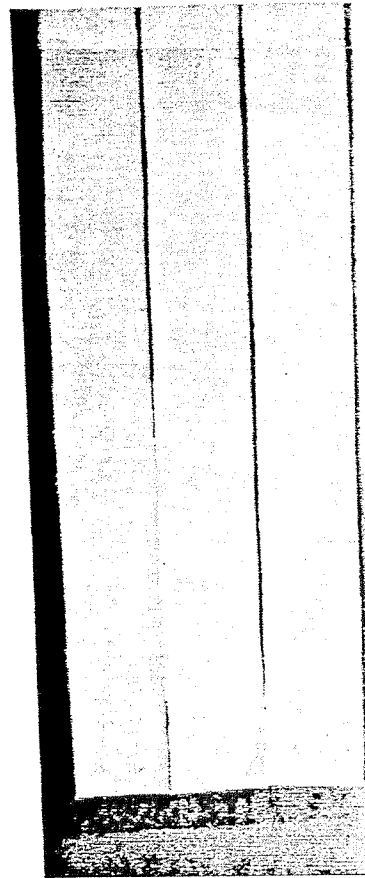


FIG. 14B

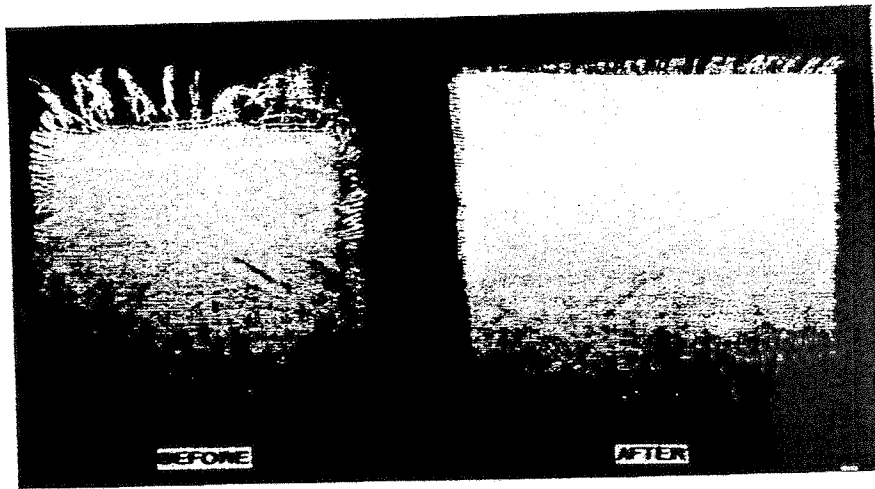


FIG. 15A

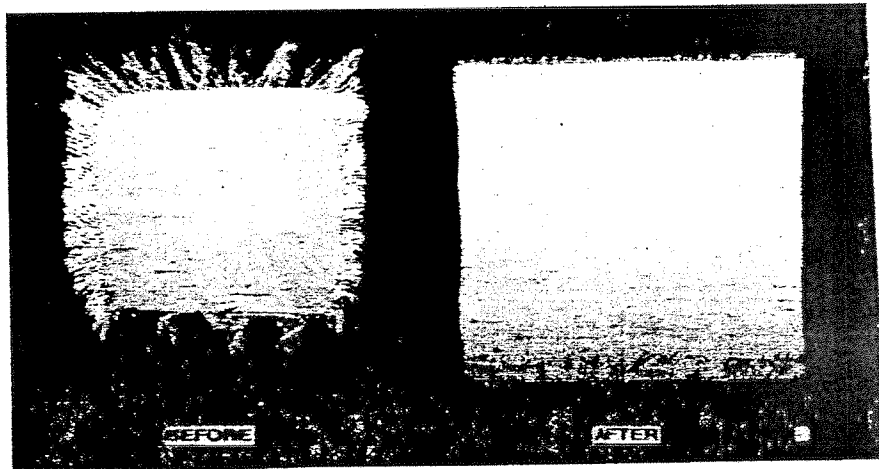


FIG. 15B



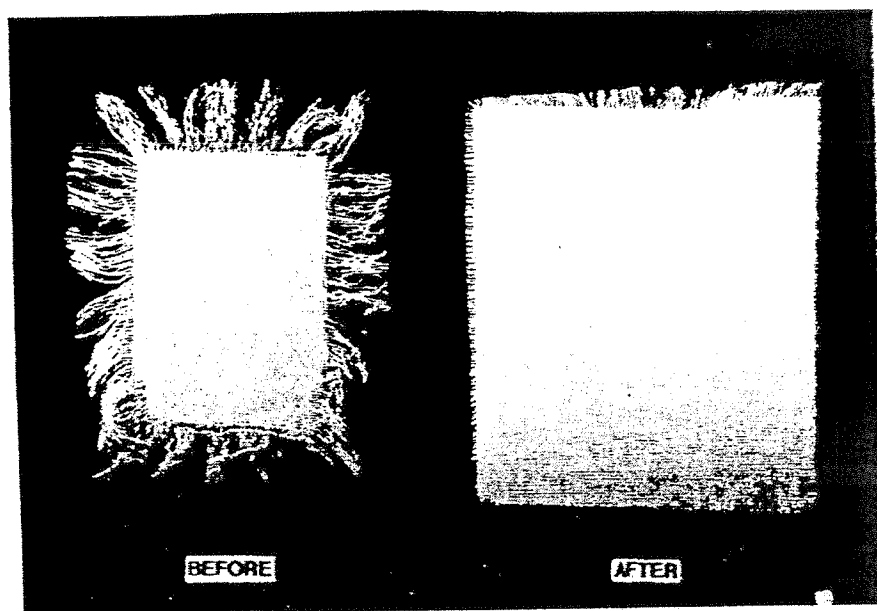


FIG. 15C



WARP

FILL

FIG. 16A

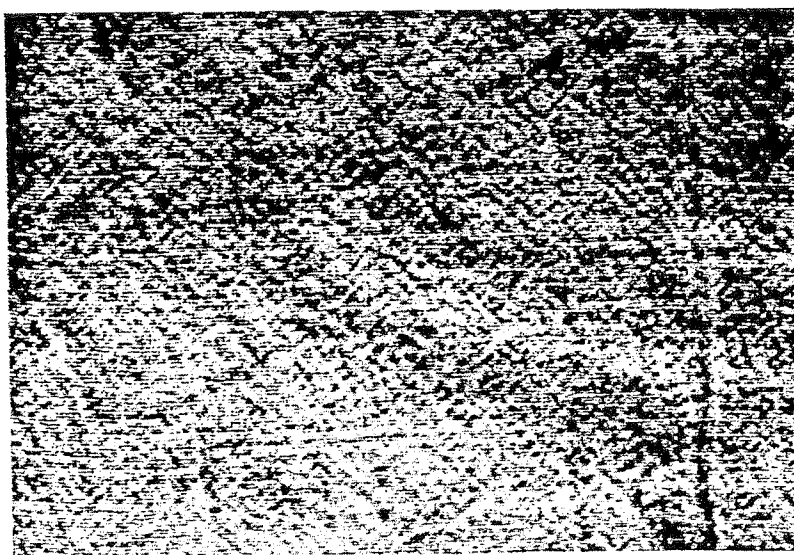
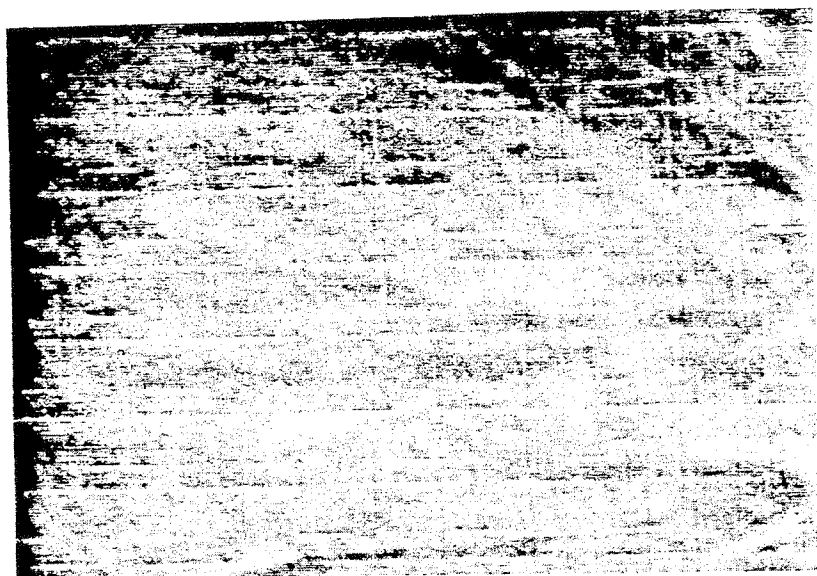


FIG. 16B



WARP

FILL

FIG. 17A

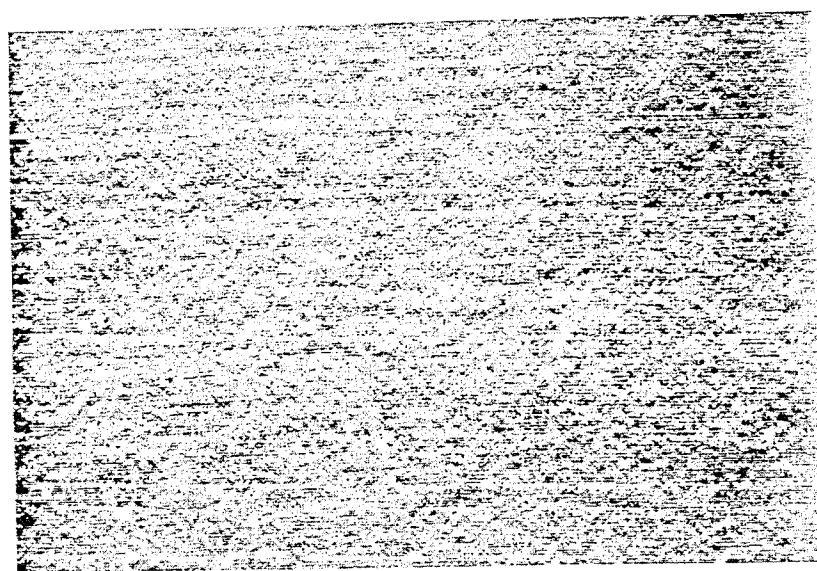
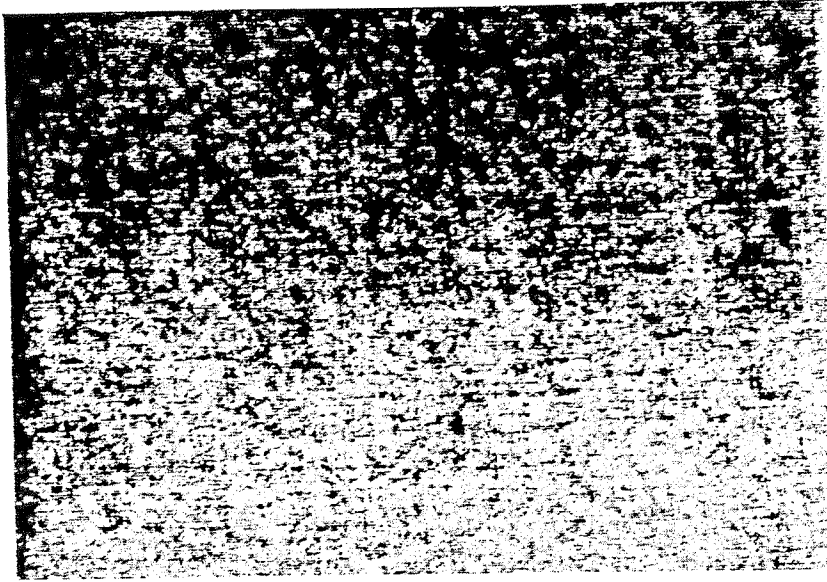


FIG. 17B



WARP

←  
FILL

FIG. 18A

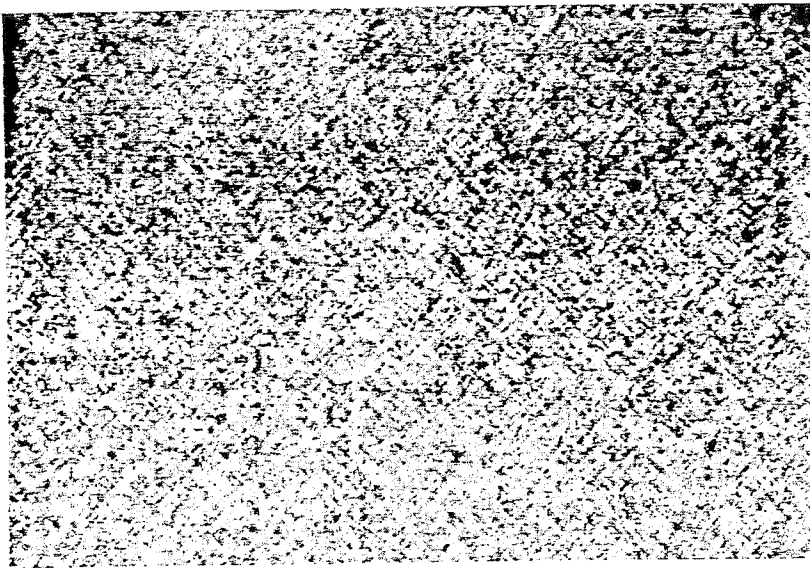


FIG. 18B

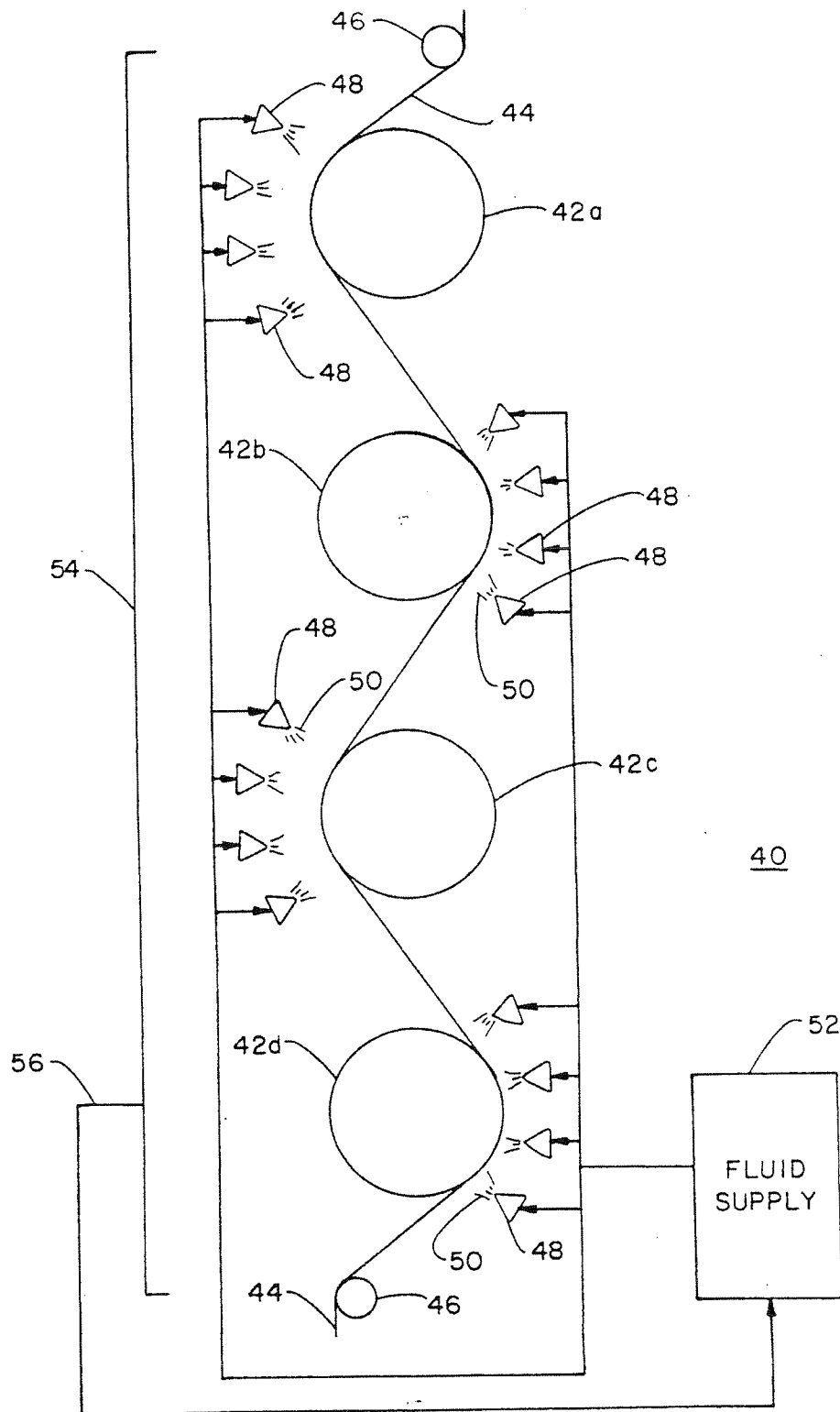


FIG. 19

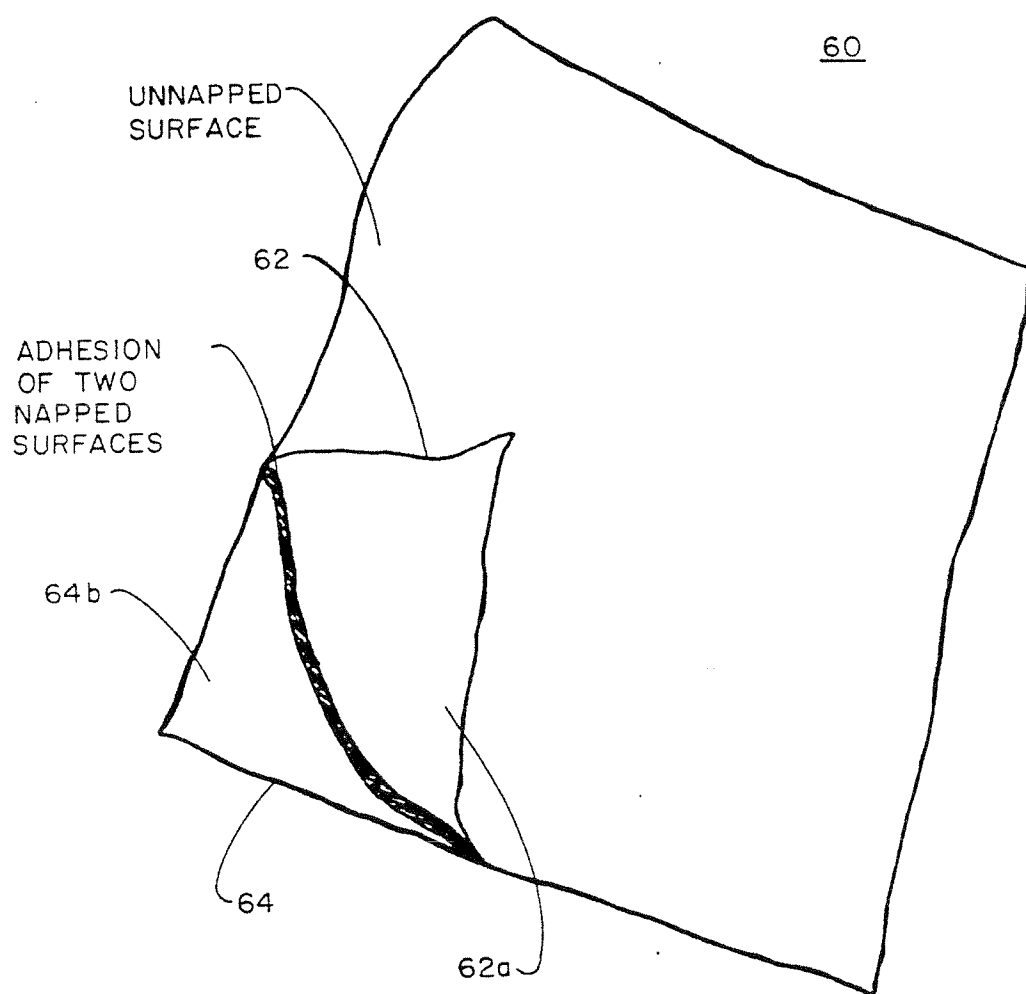


FIG. 20

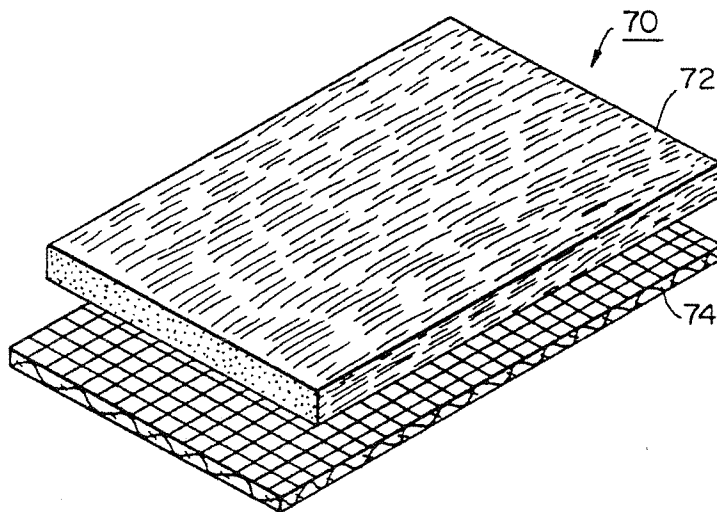


FIG. 21A

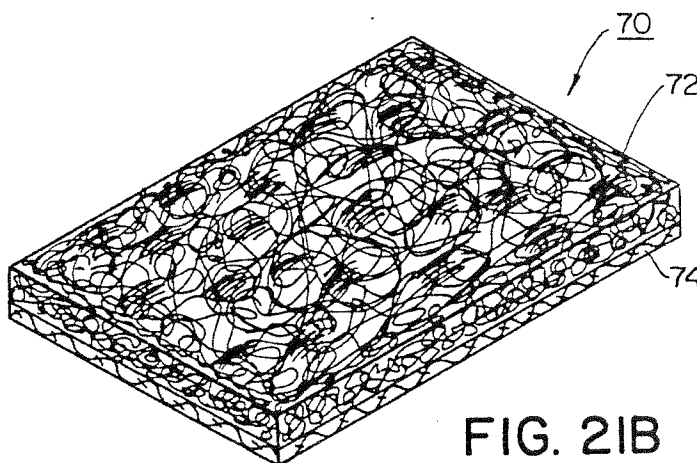


FIG. 21B

## APPARATUS AND METHOD FOR HYDROENHANCING FABRIC

### CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. Ser. No. 07/382,160, filed May 18, 1989, now U.S. Pat. No. 4,967,456, which was in turn a continuation-in-part of U.S. Ser. No. 07/184,350, filed Apr. 21, 1988, now abandoned, which was in turn a continuation-in-part of U.S. Ser. No. 07/041,542, filed Apr. 23, 1987, now abandoned.

### FIELD OF INVENTION

This invention generally relates to a textile finishing process for upgrading the quality of woven and knit fabrics. More particularly, it is concerned with a hydro-entangling process which enhances woven and knit fabrics through use of dynamic fluid jets to entangle and cause fabric yarns to bloom. Fabrics produced by the method of the invention have enhanced surface finish and durability and improved characteristics such as cover, abrasion resistance, drape, stability as well as reduced air permeability, wrinkle recovery, absorption, adsorption, shrink resistance, seam slippage, and edge fray.

### BACKGROUND ART

The quality of a woven or knit fabric can be measured by various properties, such as, the yarn count, thread count, abrasion resistance, cover, weight, yarn bulk, yarn bloom, torque resistance, wrinkle recovery, drape and hand.

Yarn count is the numerical designation given to indicate yarn size and is the relationship of length to weight.

Thread count in woven or knit fabrics, respectively, defines the number ends and picks, and wales and courses per inch of fabric. For example, the count of cloth is indicated by enumerating first the number of warp ends per inch, then the number of filling picks per inch. Thus, 68×72 defines a fabric having 68 warp ends and 72 filling picks per inch.

Abrasion resistance is the ability of a fabric to withstand loss of appearance, utility, pile or surface through destructive action of surface wear and rubbing.

Absorption is the process of gases or liquids being taken up into the pores of a fiber, yarn, or fabric.

Adsorption is the attraction of gases, liquids, or solids to surface areas of textile fibers, yarns, fabrics or any material.

Cover is the degree to which underlying structure in a fabric is concealed by surface material. A measure of cover is provided by fabric air permeability, that is, the ease with which air passes through the fabric. Permeability measures fundamental fabric qualities and characteristics such as filtration and cover.

Yarn bloom is a measure of the opening and spread of fibers in yarn.

Fabric weight is measured in weight per unit area, for example, the number of ounces per square yard.

Torque of fabric refers to that characteristic which tends to make it turn on itself as a result of twisting. It is desirable to remove or diminish torque in fabrics. For example, fabrics used in vertical blinds should have no

torque, since such torque will make the fabric twist when hanging in a strip.

Wrinkle recovery is the property of a fabric which enables it to recover from folding deformations.

5 Fabric surface durability is the resistance of a material to loss of physical properties or appearance as result of wear or dynamic operation.

Hand refers to tactile fabric properties such as softness and drapability.

10 It is known in the prior art to employ hydroentangling processes in the production of nonwoven materials. In conventional hydroentangling processes, webs of nonwoven fibers are treated with high pressure fluids while supported on apertured patterning screens. Typically, the patterning screen is provided on a drum or continuous planar conveyor which traverses pressurized fluid jets to entangle the web into cohesive ordered fiber groups and configurations corresponding to open areas in the screen. Entanglement is effected by action of the fluid jets which cause fibers in the web to migrate to open areas in the screen, entangle and intertwine.

Prior art hydroentangling processes for producing patterned nonwoven fabrics are represented by U.S. Pat. Nos. 3,485,706 and 3,498,874, respectively, to Evans and Evans et al., and U.S. Pat. Nos. 3,873,255 and 3,917,785 to Kalwaites.

Hydroentangling technology has also been employed by the art to enhance woven and knit fabrics. In such applications warp and pick fibers in fabrics are hydroentangled at crossover points to effect enhancement in fabric cover. However, conventional processes have not proved entirely satisfactory in yielding uniform fabric enhancement. The art has also failed to develop apparatus and process line technology which achieves production line efficiencies.

30 Australian Patent Specification 287821 to Bunting et al. is representative of the state of the art. Bunting impacts high speed columnar fluid streams on fabrics supported on coarse porous members. Preferred parameters employed in the Bunting process, described in the Specification Example Nos. XV-XVII, include 20 and 30 mesh support screens, fluid pressure of 1500 psi, and jet orifices having 0.007 inch diameters on 0.050 inch centers. Fabrics are processed employing multiple hydroentangling passes in which the fabric is reoriented on a bias direction with respect to the process direction in order to effect uniform entanglement. Data set forth in the Examples evidences a modest enhancement in fabric cover and stability.

Another approach of art is represented by European Patent Application 0 177 277 to Willbanks which is directed to hydropatterning technology. Willbanks impinges high velocity fluids onto woven, knitted and bonded fabrics for decorative effects. Patterning is effected by redistributing yarn tension within the fabric—yarns are selectively compacted, loosened and opened—to impart relief structure to the fabric.

50 Fabric enhancement of limited extent is obtained in Willbanks as a secondary product of the patterning process. However, Willbanks fails to suggest or teach a hydroentangling process that can be employed to uniformly enhance fabric characteristics. See Willbanks Example 4, page 40.

There is a need in the art for an improved woven textile hydroenhancing process which is commercially viable. It will be appreciated that fabric enhancement offers aesthetic and functional advantages which have application in a wide diversity of fabrics. Hydroen-

hancement improves fabric cover through dynamic fluid entanglement and bulking of fabric yarns for improved fabric stability. These results are advantageously obtained without requirement of conventional fabric finishing processes.

The art also requires apparatus of uncomplex design for hydroenhancing textile materials. Commercial production requires apparatus for continuous fabric hydroenhancing and inline drying of such fabrics under controlled conditions to yield fabrics of uniform specifications.

Accordingly, it is a broad object of the invention to provide an improved textile hydroenhancing process and related apparatus for production of a variety of novel woven and knit fabrics having improved characteristics which advance the art.

A more specific object of the invention is to provide a hydroenhancing process for enhancement of fabrics made of spun and spun/filament yarn.

Another object of the invention is to provide a hydroenhancing process having application for the fabrication of novel composite and layered fabrics.

A further object of the invention is to provide a hydroenhancing production line apparatus which is less complex and improved over the prior art.

#### DISCLOSURE OF THE INVENTION

In the present invention, these purposes, as well as others which will be apparent, are achieved generally by providing an apparatus and a related method for hydroenhancing woven and knit fabrics through dynamic fluid action. A hydroenhancing module is employed in the invention in which the fabric is supported on a member and impacted with a fluid curtain under controlled process energies. Enhancement of the fabric is effected by entanglement and intertwining of yarn fibers at cross-over points in the fabric weave or knit. Fabrics enhanced in accordance with the invention have a uniform finish and improved characteristics, such as, edge fray, drape, stability, wrinkle recovery, abrasion resistance, fabric weight and thickness.

According to the preferred method of the invention, the woven or knit fabric is advanced on a process line through a weft straightener to two in-line fluid modules for first and second stage fabric enhancement. Top and bottom sides of the fabric are respectively supported on members in the modules and impacted by fluid curtains to impart a uniform finish to the fabric. Preferred support members are fluid pervious, include open areas of approximately 25%, and have fine mesh patterns which permit fluid passage without imparting a patterned effect to the fabric. It is a feature of the invention to employ support members in the modules which include fine mesh patterned screens which are arranged in offset relation to one another with respect to the process line. This offset orientation limits fluid streaks and eliminates reed marking in processed fabrics.

First and second stage enhancement is preferably effected by columnar fluid jets which impact the fabric at pressures within the range of 200 to 3000 psi and impart a total energy to the fabric of approximately 0.10 to 2.0 hp-hr/lb.

Following enhancement, the fabric is advanced to a tenter frame which dries the fabric to a specified width under tension to produce a uniform fabric finish.

Advantage in the invention apparatus is obtained by provision of a continuous process line of uncomplex design. The first and second enhancement stations in-

clude a plurality of cross-directionally ("CD") aligned and spaced manifolds. Columnar jet nozzles having orifice diameters of approximately 0.005 inches with center-to-center spacings of approximately 0.017 inches are mounted approximately 0.5 inches from the screens.

At the process energies of the invention, this spacing arrangement provides a curtain of fluid which yields a uniform fabric enhancement. Use of fluid pervious support members which are oriented in offset relation, preferably 45°, effectively limits jet streaks and eliminates reed markings in processed fabrics.

Optimum fabric enhancement results are obtained in fabrics woven or knit of yarns including fibers with deniers and staple lengths in the range of 0.5 to 6.0, and 0.5 to 5 inches, respectively, and yarn counts in the range of 0.5 s to 50 s. Preferred yarn spinning systems of the invention fabrics include cotton spun, wrap spun, wool spun and friction spun.

Other objects, features and advantages of the present invention will be apparent when the detailed description of the preferred embodiments of the invention are considered in conjunction with the drawings which should be construed in an illustrative and not limiting sense as follows:

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view of a production line including a weft straightener, flat and drum hydroenhancing modules, and tenter frame, for the hydroenhancement of woven and knit fabrics in accordance with the invention;

FIGS. 2A and B are photographs at 10X magnification of 36×29 90° and 40×40 45° mesh plain weave support members, respectively, employed in the flat and drum enhancing modules of FIG. 1;

FIGS. 3A and B are photomicrographs at 10X magnification of a fine polyester woven fabric before and after hydroenhancement in accordance with the invention;

FIGS. 4A and B are photomicrographs at 16X magnification of the control and processed fabric of FIGS. 3A and B;

FIGS. 5A and B are photomicrographs at 10X magnification of a control and hydroenhanced woven acrylic fabric;

FIGS. 6A and B are photomicrographs at 10X magnification of a control and hydroenhanced acrylic fabric woven of wrap spun yarn;

FIGS. 7A and B are photomicrographs at 10X magnification of a control and hydroenhanced acrylic fabric woven of wrap spun yarn;

FIGS. 8A and B are photomicrographs at -10X magnification of a control and hydroenhanced acrylic fabric including open end wool spun yarn;

FIGS. 9A and B are photomicrographs at 16X magnification of a control and hydroenhanced wool nylon (80/20%) fabric;

FIGS. 10A and B are photomicrographs at 16X magnification of a control and hydroenhanced spun/filament polyester/cotton twill fabric;

FIGS. 11A and B are photomicrographs at 16X magnification of a control and hydroenhanced doubleknit fabric;

FIGS. 12A and B are front and back side photomicrographs at 16X magnification of a control wall covering fabric;

FIGS. 13A and B are front and back side photomicrographs at 16X magnification of the wall covering

fabric of FIGS. 12A and B hydroenhanced in accordance with the invention;

FIG. 14 is a photomicrograph at 0.09X magnification of a control and hydroenhanced acrylic fabric strips, the fabric of FIGS. 7A and B, showing the reduction in fabric torque achieved in the invention process;

FIGS. 15 A-C are photomicrographs at 0.23X magnification, respectively, of the woven acrylic fabrics of FIGS. 5, 7 and 8, 0 comprised of wrap spun and open end wool spun yarns, showing washability and wrinkle characteristics of control and processed fabrics;

FIGS. 16A and B are photomicrographs at approximately 1X magnification of control and hydroenhanced acrylic fabric including wrap spun polyester yarns, showing washability and surface durability characteristics results obtained in the invention process;

FIGS. 17A and B are photomicrographs at approximately 1X magnification of control and hydroenhanced 100% polyester fabric which includes slub yarns, showing washability surface durability characteristics results obtained in the invention process

FIGS. 18A and B are photomicrographs at IX magnification of control and hydroenhanced 80% wool and 20% nylon fabric, showing washability surface durability characteristics results obtained in the invention process;

FIG. 19 is a schematic view of an alternative production line apparatus for the hydroenhancement of woven and knit fabrics in accordance with the invention;

FIG. 20 illustrates a composite fabric including napped fabric components which are bonded into an integral structure employing the hydroenhancing process of the invention; and

FIG. 21A and B, respectively, are enlarged schematic illustrations, of a nonwoven-textile fabric composite before and subsequent to enhancement and lamination in accordance with the invention process.

#### BEST MODE OF CARRYING OUT THE INVENTION

With further reference to the drawings, FIG. 1 illustrates a preferred embodiment of a production line of the invention, generally designated 10, for hydroenhancement of a fabric 12 including spun and/or spun/-filament yarns. The line includes a conventional weft straightener 14, flat and drum enhancing modules 16, 18, and a tenter frame 20.

Modules 16, 18 effect two sided enhancement of the fabric through fluid entanglement and bulking of fabric yarns. Such entanglement is imparted to the fabric in areas of yarn crossover or intersection. Control of process energies and provision of a uniform curtain of fluid produces fabrics having a uniform finish and improved characteristics including, edge fray, torque, wrinkle recovery, cupping, drape, stability, abrasion resistance, fabric weight and thickness.

#### METHOD AND MECHANISM OF THE ENHANCING MODULES

Fabric is advanced through the weft straightener 14 which aligns the fabric weft prior to processing in enhancement modules 16, 18. Following hydroenhancement, the fabric is advanced to the tenter frame 20, which is of conventional design, where it is dried under tension to produce a uniform fabric of specified width.

Module 16 includes a first support member 22 which is supported on an endless conveyor means including rollers 24 and drive means (not shown) for rotation of

the rollers. Preferred line speeds for the conveyor are in the range of 10 to 500 ft/min. Line speeds are adjusted in accordance with process energy requirements which vary as a function of fabric type and weight.

Support member 22, which preferably has a flat configuration, includes closely spaced fluid pervious open areas 26. A preferred support member 22, shown in FIG. 2A, is a  $36 \times 29$  90° mesh plain weave having a 23.7% open area, fabricated of polyester warp and shute round wire. Support member 22 is a tight seamless weave which is not subject to angular displacement or snag. Specifications for the screen, which is manufactured by Albany International, Appleton Wire Division, P.O. Box 1939, Appleton, Wis. 54913 are set forth in Table I.

TABLE I

Property	Support Screen Specifications	
	36 × 29 90° flat mesh	40 × 40 45° drum mesh
Wire	polyester	stainless steel
Warp wire	.0157	0.010
Shute wire	.0157	0.010
Weave type	plain	plain
Open area	23.7%	36%

Module 16 also includes an arrangement of parallel and spaced manifolds 30 oriented in a cross-direction ("CD") relative to movement of the fabric 12. The manifolds which are spaced approximately 8 inches apart each include a plurality of closely aligned and spaced columnar jet orifices 32 which are spaced approximately 0.5 inches from the support member 22.

The jet orifices have diameters and center-to-center spacings in the range of 0.005 to 0.010 inches and 0.017 to 0.034 inches, respectively, and are designed to impact the fabric with fluid pressures in the range of 200 to 3000 psi. Preferred orifices have diameters of approximately 0.005 inches with center-to-center spacings of approximately 0.017 inches.

This arrangement of fluid jets provides a curtain of fluid entangling streams which yield optimum enhancement in the fabric. Energy input to the fabric is cumulative along the line and preferably set at approximately the same level in modules 16, 18 (two stage system) to impart uniform enhancement to top and bottom surfaces of the fabric. Effective first stage enhancement of fabric yarn is achieved at an energy output of at least 0.05 hp-hr/lb and preferably in the range of 0.1 to 2.0 hp-hr/lb.

Following the first stage enhancement, the fabric is advanced to module 18 which enhances the other side of the fabric. Module 18 includes a second support member 34 of cylindrical configuration which is supported on a drum. The member 34 includes closely spaced fluid pervious open areas 36 which comprise approximately 36% of the screen area. A preferred support member 34, shown in FIG. 2B, is a  $40 \times 40$  45° mesh stainless steel screen, manufactured by Appleton Wire, having the specifications set forth in Table I.

Module 18 functions in the same manner as the planar module 16. Manifolds 30 and jet orifices 32 are provided which have substantially the same specifications as in the first stage enhancement module. Fluid energy to the fabric of at least 0.5 hp-hr/lb and preferably in the range of 0.1 to 2.0 hp-hr/lb effects second stage enhancement.

Conventional weaving processes impart reed marks to fabrics. Illustrations of such markings are shown in FIGS. 3A and 4A which are photomicrographs at 10X

and 16X magnification of a polyester LIBBEY brand fabric style no. S/x-A805 (see Table II). Reed marks in FIGS. 3A and 4A are designated by the letter "R".

The invention overcomes this defect in conventional weaving processes through use of a single and preferably two stage hydroenhancement process. Advantage is obtained in the invention process by orienting the drum support member 34 in offset relation, preferably 45°, relative to machine direction ("MD") of the hydroenhancing line. See FIGS. 2A and B.

Support members 22 and 34 are preferably provided with fine mesh open areas which are dimensioned to effect fluid passage through the members without imparting a patterned effect to the fabric. The preferred members have an effective open area for fluid passage in the range of 17-40%.

Comparison of the control and processed polyester fabric of FIGS. 3A, B and 4A, B illustrates the advantages obtained through use of the enhancement process. Reed marks R in control polyester fabric are essentially eliminated through enhancement of the fabric. The offset screen arrangement is also effective in diminishing linear jet streak markings associated with the enhancement process.

#### EXAMPLES I-XIII

FIGS. 3-15 illustrate representative woven and knit fabrics enhanced in accordance with the method of the invention, employing test conditions which simulate the line of FIG. 1 (hereinafter the "Prototype FIG. 1 line"). Table II sets forth specifications for the fabrics illustrated in the drawings.

As in the FIG. 1 line, the test manifolds 30 were spaced approximately 8 inches apart in modules 16, 18, and provided with densely packed columnar jet orifices 32 of approximately 60/inch. Orifices 32 each had a diameter of 0.005 inches and were spaced approximately 0.5 inches from the first and second support members 22, 34.

The process line of FIG. 1 includes enhancement modules 16, 18 which, respectively, are provided with six manifolds. In the Examples, modules 16, 18 were each fitted with two manifolds 34. To simulate line conditions, the fabrics were advanced through multiple runs on the line. Three processing runs in each two manifold module was deemed to be equivalent to a six manifold module.

Fabrics were hydroenhanced at process pressures of approximately 1500 psi. Line speed and cumulative energy output to the modules were respectively maintained at approximately 30 fpm and 0.46 hp-hr/lb. Adjustments in the line speed and fluid pressure were made to accommodate differences in fabric weight for uniform processing and to maintain the preferred energy level.

Fabrics processed in the Examples exhibited marked enhancement in aesthetic appearance and quality including, characteristics such as cover, bloom, abrasion resistance, drape, stability, and reduction in seam slippage, and edge fray.

Tables III-XI set forth data for fabrics enhanced in accordance with invention on the test process line. Standard testing procedures of The American Society for Testing and Materials (ASTM) were employed to test control and processed characteristics of fabrics. Data set forth in the Tables was generated in accordance with the following ASTM standards:

Fabric Characteristic	ASTM Standard
Weight	D3776-79
Thickness	D1777-64 (Ames Tester)
Tensile Load	D1682-64 (1975) (Cut strip/grab)
Elongation	D1682-64 (1975)
Air Permeability	D737-75 (1980) (Frazier)
Thread Count	D3775-79
Ball Burst	D3787-80A
Slippage	D4159-82
Tongue Tear	D2261-71
Wrinkle Recovery	D1295-67 (1972)
Abrasion Resistance	D3884-80
Pilling	D3514-81

Washability tests were conducted in accordance with the following procedure. Weight measurements ("before wash") were taken of control and processed fabric samples each having a dimension of 8.5" x 11" (8.5" fill direction and 11" warp direction). The samples were then washed and dried in conventional washer and dryers three consecutive times and "after wash" measurements were taken. The percent weight loss of the pre and post wash samples was determined in accordance the following formula:

$$\% \text{ weight loss} = D/B \times 100$$

where, B=before wash sample weight; A=after wash sample weight; and D=B-A.

Photomicrographs of the fabrics, FIGS. 4-15, illustrate the enhancement in fabric cover obtained in the invention. Attention is directed to open areas in the unprocessed fabrics, photographs designated A, these areas are of reduced size in the processed fabrics in the photographs designated B. Hydroenhancement caused fabric yarns to bloom and entangle at cross-over points, filling in open areas to improve cover and reduce air permeability in the fabrics.

FIGS. 12 and 13 are photomicrographs of a HYTEX brand wall covering fabric, manufactured by Hytex, Inc, Randolph, Mass. A multi-textured surface appearance of the fabric is provided by yarns which are woven through discrete areas of the front fabric surface. Free floating weave stitches, designated by the letter "S" in FIGS. 12B and 13B, are formed on the backside of the fabric.

Hydroenhancement of HYTEX wall covering fabric secured the free-floating stitches S to the fabric backside enhancing fabric stability and cover. See FIGS. 12B, 13B. In wall covering applications, fabric enhancement and associated stabilizing effects reduces or eliminates the need for adhesive backcoatings. Enhancement of the fabric also limits wicking of wall cover application adhesives through the fabric. Further advantage is obtained when enhanced fabrics are used in acoustic applications; elimination of backcoating reduces sound reflection and furthers efficient transmission of sound through the fabric.

TABLE II

Fabric Specifications	FIG(S)
Fiber Brand and Style Designation	
NOMEX S/x-A805*	3A,B, 4A,B
Fiber: 2 denier-1.9 inch	
Yarn: Open end cotton spun 17s	
LIBBEY S/022**	5A,B
Warp:	
Fiber: 3 denier - 1.5 inch acrylic	

TABLE II-continued

Fabric Specifications		FIG(S).
Fiber Brand and Style Designation		
Yarn: Open end cotton spun 9s 28 ends per inch		
Fill:		
Fiber: 3 denier - 3 inch acrylic		
Yarn: Open end wool spun 4s 14, 16 or 18 picks per inch		6A,B
LIBBEY S/x-1160		
Fiber: 3 denier-3 inch acrylic		
Yarn: Wrap spun w/100 den textured polyester 4s 14 ends $\times$ 16 picks per inch		7A,B
LIBBEY S/406		
14A,B		
Warp:		
Fiber: 3 denier - 1.5 inch acrylic		
Yarn: Open end cotton spun 9s 28 ends per inch		
Fill:		
Fiber: 3 denier - 3 inch acrylic		
Yarn: Hollow spun 6 twists/inch 4s 14; 16 or 18 picks per inch		8A,B
LIBBEY S/152		
Warp:		
Fiber: 3 denier - 2.5 inch acrylic		
Yarn: Open end cotton spun 4s 14 ends per inch		
Fill:		
Fiber: 3 denier - 3 inch acrylic		
Yarn: Open end wool spun 2.6s 14, 16 or 18 picks per inch		9A,B
Guilford Wool/Nylon		
80% wool/20% nylon		
Polyester/cotton (53/47)		10A,B
Weight: 10 ounces/yd2		
Yarn: Spun Filament		
Weave: 3 $\times$ 1 Twill		
Thread Count: 120 $\times$ 38		
50% Polyester/50% cotton Doubleknit		11A,B
Yarn: wrap spun with 100 denier polyester wrap		
HYTEX Wall covering***		12, 13

\*LIBBEY is a trademark of W. S. Libbey Co., One Mill Street, Lewiston, ME 04240.

\*\*NOMEX is a trademark of E.I. Du Pont de Nemours and Company, Wilmington, Del.

\*\*\*HYTEX is a trademark of Hytex, Inc., Randolph, MA.

TABLE III

Nomex A805 - FIG. 4			
	Control	Processed	% Change
Weight (gsy)	195	197	+1.0
Thickness (mils)	42	42	0
Air Perm. (ft <sup>3</sup> /ft <sup>2</sup> /min)	331	156	-52.9
Strip Tensile (lbs/in)			
warp	115	132	+14.8
fill	59	47	-20.3
Elongation (%)			
warp	48	50	+4.2
fill	62	71	+14.5

TABLE IV

022/6075 (16 ppi) - FIG. 5			
	Control	Processed	% Change
Weight (gsy)	158	165	+4.4
Thickness (mils)	48	49	+2.1
Air Perm. (ft <sup>3</sup> /ft <sup>2</sup> /min)	406	259	-36.2
Strip Tensile (lbs/in)			
warp	34	36	+5.9
fill	37	31	-16.2
Elongation (%)			
warp	33	27	-18.2

TABLE IV-continued

022/6075 (16 ppi) - FIG. 5			
	Control	Processed	% Change
5 fill	27	28	+3.7
Seam Slippage (lbs/in)			
warp	5	60	+1100.0
fill	7	55	+685.7
Tongue Tear (lbs)			
warp	18	10	-44.4
fill	21	8	-61.9
Wt. Loss In Wash (%)	37	5	-86.5
Wrinkle Recovery* (recovery angle)	123*	138*	+12.2

\*Under ASTM test standards (D1295-67) improvements in the wrinkle recovery of a fabric are indicated by an increase in the recovery angle.

TABLE V

Libbey S/x-1160 - FIG. 6			
	Control	Processed	% Change
20 Weight (gsy)	146.8	160.2	9.1
Thickness (mils)	38.1	52.7	38.3
Air Perm. (ft <sup>3</sup> /ft <sup>2</sup> /min)	457.2	188.5	-58.8
Grab Tensile (lbs/in)			
warp	80.2	89.3	11.4
fill	105.0	111.4	6.1
Elongation (%)			
warp	30.0	34.0	13.3
fill	32.0	46.0	43.8
Ball Burst (lbs)	190	157	-17.4

TABLE VI

406/6075 (16 ppi) - FIG. 7			
	Control	Processed	% Change
35 Weight (gsy)	159	166	+4.4
Thickness (mils)	48	50	+4.2
Air Perm. (ft <sup>3</sup> /ft <sup>2</sup> /min)	351	184	-47.6
Strip Tensile (lbs/in)			
warp	42	36	-14.3
fill	66	58	-12.1
Elongation (%)			
warp	23	31	+34.8
fill	49	33	-32.7
Seam Slippage (lbs)			
warp	29	36	+89.5
fill	21	76	+261.9
Tongue Tear (lbs)			
warp	23	18	-21.7
fill	19	15	-11.1
Wt. Loss In Wash (%)	28	4	-85.7
Wrinkle Recovery (recovery angle)	140*	148*	+5.7

TABLE VII

152/6076 (16 ppi) - FIG. 8			
	Control	Processed	% Change
55 Weight (gsy)	231	257	+11.3
Thickness (mils)	259	238	-8.1
Air Perm. (ft <sup>3</sup> /ft <sup>2</sup> /min)	204	106	-48.0
Strip Tensile (lbs/in)			
warp	48	58	+20.8
fill	56	72	+28.6
Elongation (%)			
warp	33	33	0
fill	34	39	+14.7
Seam Slippage (lbs)			
warp	64	81	+26.6
fill	78	112	+43.6
Tongue Tear (lbs)			

TABLE VII-continued

152/6076 (16 ppi) - FIG. 8			
	Control	Processed	% Change
warp	21	18	-14.3
fill	17	15	-11.8
Wt. Loss In Wash (%)	—	—	—
Wrinkle Recovery (recovery angle)	117*	136*	+16.2

TABLE VIII

Guilford Wool (80% wool/20% nylon) - FIG. 9			
	Control	Process	% Change
Air Perm.	243	147	-39.5

TABLE IXA

Spun/Filament - Bottom Weights - FIG. 10								
	Sample #1		Sample #2		Sample #3		Sample #4	
	Control	Proc	Control	Proc	Control	Proc	Control	Proc
Weight (gsy)	259.2	275.4	240.3	248.4	286.2	297.2	267.3	280.8
Thickness (mils)	39.7	39.2	35.0	35.3	44.2	41.5	40.0	38.0
Strip Tensiles (lbs./in.)								
Warp	206.98	208.87	195.50	200.86	183.09	189.95	206.43	207.87
Fill	85.55	56.23	84.21	71.83	80.88	83.01	80.16	82.14
Normalized Tensiles (lbs./in.)								
Warp	7.98	7.58	8.05	8.09	6.40	6.39	7.65	7.40
Fill	3.30	2.04	2.54	2.89	2.83	2.79	3.03	2.93
Elongation (%)								
Warp	42.0	55.3	36.5	39.1	40.9	43.5	46.1	51.2
Fill	23.6	25.6	24.0	20.0	23.5	20.3	22.9	22.4
Air Perm. (ft. <sup>3</sup> /ft. <sup>2</sup> /min)	50.9	27.3	43.5	28.8	45.8	21.8	51.4	25.4
Thread Count (wxf)	120 × 40	120 × 41	120 × 45	120 × 45	120 × 38	120 × 42	120 × 42	120 × 43
Mullen Burst (lbs.)	161.2	222.2	187.2	228.8	161.0	217.8	205.0	242.2
Normalized Burst (lbs./g × 10 <sup>2</sup> )	62.2	80.7	77.9	92.1	56.2	73.3	76.7	86.3

TABLE IXB

Abrasion - Spun Filament-Bottom Weights - FIG. 10					
ASTM Standard - Twill side up; 500 cycles; 500 g weight; H-18 wheels					
Sample	Weight Before (g)	Weight After (g)	Weight Loss (g)	% Loss	% Improvement
1C	3.32	3.02	0.30	9.0	
1P	3.36	3.13	0.23	6.9	23%
2C	4.64	4.16	0.48	10.4	
2P	4.83	4.57	0.26	5.4	48%
3C	4.73	4.47	0.26	5.5	
3P	4.91	5.13	0.22	4.5	18%
4C	4.47	4.18	0.29	6.5	
4P	4.71	4.53	0.18	3.8	41%

TABLE X

Doubleknit - FIG. 11			
	Control	Pro-cessed	% Change
Air Perm. (Ft <sup>3</sup> /ft <sup>2</sup> min)	113.1	95.1	-15.9
Abrasion ASTM (D-3884-80): 250 Cycles, H-18 wheel	1.0	0.6	-40.0
Pilling (1-5 rating) ASTM (D-3914-81): 300 cycles	4.3	4.3	0

FIGS. 14A, B are photomicrographs of control and processed acrylic vertical blind fabric, manufactured by W. S. Libbey, style designation S/406. Enhancement of the fabric reduces fabric torque which is particularly advantageous in vertical blind applications. The torque

reduction test of FIGS. 14A, B employed fabric strips 84" long and 3.5" wide, which were suspended vertically without restraint. Torque was measured with reference to the angle of fabric twist from a flat support surface. As can be seen in the photographs, a torque of 90° in the unprocessed fabric, FIG. 14A, was eliminated in the enhancement process.

FIGS. 15A-C are macrophotographs of control and processed acrylic fabrics, LIBBEY style nos. 022, 406 and 152, respectively, which were tested for washability. Unprocessed fabrics exhibited excessive fraying and destruction, in contrast to the enhanced fabrics which exhibit limited fraying and yarn (weight) loss. Table XI sets forth washability test weight loss data.

TABLE XI

022, 406, 152 - FIGS. 15A-C		
Percent Weight Loss (3 wash/dry cycles)		
Sample	Control	Processed
022	36.5	5.0
406	28.0	4.0
152	28.1	7.2

In the foregoing Examples, the enhancement process of the invention is shown to yield improved textile finishing features such as, surface cover, abrasion resistance, wrinkle recovery, tensile strength and air permeability. Additional fabric features which may be obtained in the invention include, enhancement of fabric surface durability, absorption and adsorption, and shrinkage reduction. Further, advantageous fabric features are obtained in particular material applications of the invention enhancement process. For example, it has been found that enhancement of wool fabrics yields dense and compact fabrics which are shrink resistant. In another application of the invention technology improvements in fabric flame retardancy have been obtained in the processing of polyester based fabrics.

Examples illustrating further applications and embodiments of the invention are set forth below. As in the prior Examples, fabrics were processed on the Prototype FIG. 1 line described in the previous Examples. Fabrics were hydroenhanced at process pressures of approximately 1500 psi. Line speed and cumulative

energy output to the entanglement modules were respectively maintained at approximately 30 fpm and 0.5 hp-hr/lb. Adjustments in the line speed and fluid pressure were made to accommodate differences in fabric weight for uniform processing and to maintain the preferred energy levels.

#### EXAMPLE XIV

##### Fabric Surface Durability

Conventional finishing processes for imparting surface durability to fabrics employ chemical binders which lock fabric fibers into stable orientations. Such "durable" or "permanent" press processes stiffen fabric finishes and adversely effect the hand and drape characteristics in fabrics. The hydroenhancement process of

shrinkage measurements were recorded with reference to line markings. As in prior Example XIV, laundering conditions approximated standards set forth in the AATCC Technical Manual, Test Method 124-1984.

Comparison of processed and control test data demonstrates that the invention enhancement obtains a measurable reduction in shrink resistance. For example, after five wash/dry cycles, enhanced 65% wool/-PET% exhibits a 6.9 percent shrinkage as compared to 14.4 percent shrinkage in an unprocessed control.

Attention is directed Table XIV which sets forth data for shrinkage in wool fabrics. It will be seen that stabilization in wool fabrics provides a "washable wool" without requirement of conventional chemical finishing treatment.

TABLE XII

SHRINKAGE - 5 WASH/DRY CYCLES							
Warp/Fill (W/F) Measurements							
Original Sample 10" x 10" Sample		Measurement After Wash (inches)		Percent Shrinkage		Percent Area Shrinkage	
		Cont.	Proc.	Cont.	Proc.	Cont.	Proc.
Greige Cotton	W	8.8	8.9	12	11	16.4	6.6
Osnaburg	F	9.5	10.5	5	+5*		
Bleached Cotton	W	8.3	8.5	17	15	12.9	2.3
Osnaburg	F	10.5	11.5	+5*	+1.5*		
Wool/PET	W	9.3	9.6	7	4	14.4	6.9
65/35	F	9.2	9.7	8	3		
Acrylic Tweed	W	9.3	9.8	7	2	13.5	3.0
	F	9.3	9.9	7	1		
Acrylic Beige	W	9.3	9.9	7	1	12.6	2.0
	F	9.4	9.9	6	1		
PET	W	9.5	9.8	5	2	6.0	1.0
	F	9.9	10.1	1	+1		

\*" + " indicates stretch - only in cotton fabrics

the invention imparts improved surface durability to fabrics without requirement of chemical treatment finishes. This result is obtained through stabilization of fabric matrix structures in the enhancement process through entanglement of yarns. Enhancement simulates fiber locking mechanisms of conventional chemical treatments.

FIGS. 16A,B-18A,B respectively, are macrophotographs of control and processed fabrics as follows: 1) acrylic fabric including wrap spun polyester yarn, 2) 100% polyester fabric including slub yarns, count of 16x10 yarns/in<sup>2</sup> and weight of 8 ounces/yd<sup>2</sup>, and 3) Guilford 80% wool/20% nylon fabric (see Table II).

Durability was tested by subjecting the fabric samples to five (5) repeated wash-dry laundering treatments. Test conditions approximated conventional home laundry warm water washing and hot air drying conditions as defined in the AATCC Technical Manual, Test Method 124-1984. Control and process fabrics were mounted on boards and illuminated at an oblique angle by fluorescent light for macrophotographic comparison. Unprocessed fabrics were characterized by a roughened, mottled and nubby finish as compared with enhanced fabrics which exhibit smooth and pressed surface finishes.

#### EXAMPLE XV

##### Shrink-Resistance

Enhanced fabrics of the invention exhibit enhanced shrink resistance. Tables XII-XIV set forth shrinkage test data for wash/dry and dry cleaning processing of representative control and enhanced fabrics. Fabric shrinkage was measured by marking test fabrics with 10"x10" measurement lines. Following processing,

TABLE XIII

SHRINKAGE - 5 Dry Cleaning Cycles*				
WOOL/PET and WOOL/NYLON				
Warp/Fill (W/F) Measurements				
Original Sample: 10" x 10"				
	Wool/Pet 65/35		Wool/Nylon 80/20	
	Size (in.)	Percent Shrinkage	Size (in.)	Percent Shrinkage
Control				
W	9.8	2.0	9.75	2.5
F	9.85	1.5	9.8	2.0
Processed				
W	9.8	2.0	9.8	2.0
F	9.85	1.5	9.9	1.0

\*Dry cleaning fluid: Perichlorethylene

TABLE XIV

WOOL SHRINKAGE		
Samples marked 10" x 10"		
	Length	Width
Fine White Wool		
Processed	9.75	9.7
Shrinkage (%)	2.5	3.0
Processed - 5 Wash/Dry	8.7	8.7
Shrinkage (%)	13.0	13.0
Control - 5 Wash/Dry	8.3	8.2
Shrinkage (%)	17.0	18.0
Coarse Blue Wool		
Processed	9.7	9.3
Shrinkage (%)	3.0	7.0
Processed - 5 Wash/Dry	8.0	8.0
Shrinkage (%)	20.0	20.0
Control - 5 Wash/Dry	7.8	7.7

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TABLE XIV-continued

WOOL SHRINKAGE Samples marked 10" x 10"		
	Length	Width
Shrinkage (%)	22.0	23.0

## EXAMPLE XVI

## Absorption and Adsorption

Enhanced fabrics of the invention exhibit increased absorption and adsorption properties. Table XV sets forth data for ASTM water retention data for representative fabrics processed in accordance with the invention.

TABLE XV

Fabric	Absorptive Capacity Test Standard: ASTM D1117 - 5 sections		
	Untreated	Treated	Percent Increase
Osna burg	11.7	12.9	10.3
100% Cotton			
Acrylic	16.8	21.8	29.8
Wool/PET (65/35)	19.7	23.2	17.8
PET	11.8	15.0	27.1

## EXAMPLE XVII

## Hydromilled Wood

Conventional fulling or felting processes are em-

16

processes the fabric is subjected to moisture, heat, friction, chemicals and pressure which cause the fabric fibers to mat and densify into a stable structure. Advantageously, it has found that comparable results are obtained in the present invention without requirement of conventional chemical and mechanical processing and associated degradation of the fabric.

Tables XVIA-C set forth comparative data for conventional fulled and hydroenhanced grieg state wool fabrics. Control and conventional processed fabrics were obtained from Carleton Woolen Mills, Winthrop, Me.. The control grieg state fabrics respectively had weights of 180.5, 252.7 and 145.9 gsy prior to application of hydroenhancing and conventional fulling processing. Hydroenhancement data is set forth for processing of each control fabric at energies of 0.5 and 1.0 hp-hr/lb. It will be seen that fabrics processed in accordance with the invention have physical properties which simulate those of the conventionally fulled fabrics.

Wool hydroenhancing ("Hydromilling") trials set forth in Tables XVIA-C were processed employing the Prototype FIG. 1 line. It is believed that further processing advantage in the hydromilling process could be obtained by use of hot fluid in the entanglement modules. For example, use of hot water in the line will further matting and mechanical entanglement of wool fibers. To this end it would also be advantageous to employ a hot water bath or felting pre-entanglement process step in the invention.

TABLE XVI-A

	HYDROMILLED WOOL - Sample 1			
	PROCESSED			
	CONTROL*	.5 hphr/lb	1 hphr/lb	FINISHED**
WEIGHT (gsy)	180.5	179.6	173.9	190.9
THICKNESS (mils)	53.2	53.6	52.9	34.3
AIR PERM (cfm)	329.5	214.0	212.0	117.4
GRAB TENSILE (lbs)				
WARP	43.0	43.2	41.6	35.5
FILL	31.2	29.4	31.7	19.1
ELONGATION (%)				
WARP	42.4	48.5	41.1	24.5
FILL	37.5	39.2	42.0	42.4
TONGUE TEAR (lbs)				
WARP	6.5	5.2	5.4	3.0
FILL	8.3	7.0	6.3	4.4
% SHRINKAGE (after 5 wash/dry)				
WARP	21.0	17.0		27.8
FILL	16.0	17.0		13.1
TABER ABRASION (% weight loss)	4.3	4.0	4.1	5.0
% WOOL (Chem. extraction)	99.9	100.0		

\*Grieg state wool, manufactured by Carleton Woolen Mills, Winthrop, Maine.

\*\*Conventional processed wool offered by Carleton Woolen Mills.

ployed to finish woolen and worsted fabrics. In such

TABLE XVI-B

	HYDROMILLED WOOL - Sample 2			
	PROCESSED			
	CONTROL*	.5 hphr/lb	1 hphr/lb	FINISHED
WEIGHT (gsy)	252.7	250.8	254.7	285.5
THICKNESS (mils)	69.9	70.8	71.4	106.6
AIR PERM (cfm)	214.5	127.3	120.6	138.6
GRAB TENSILE (lbs)				
WARP	52.0	58.9	63.8	55.1
FILL	53.4	56.5	69.5	35.9
ELONGATION (%)				
WARP	40.0	46.1	45.9	35.5
FILL	43.2	50.9	54.3	50.7

TABLE XVI-B-continued

HYDROMILLED WOOL - Sample 2				
PROCESSED				
	CONTROL*	.5 hphr/lb	1 hphr/lb	FINISHED
TONGUE TEAR (lbs)				
WARP	16.7	14.8	14.6	6.6
FILL	17.5	15.4	13.9	8.7
% SHRINKAGE (after 5 wash/dry)				
WARP	17.0	15.0		16.9
FILL	14.0	7.0		5.6
TABER ABRASION (% weight loss)	3.7	3.6	3.0	4.4
% WOOL (Chem. extraction)	80.3	79.8		

\*Griege state wool manufactured by Carleton Woolen Mills, Winthrop, Maine.

TABLE XVI-C

HYDROMILLED WOOL - Sample 3				
PROCESSED				
	CONTROL*	.5 hphr/lb	1 hphr/lb	FINISHED
WEIGHT (gsy)	145.9	147.7	147.3	146.9
THICKNESS (mils)	36.6	39.7	40.5	23.2
AIR PERM (cfm)	311.3	193.0	189.0	134.4
GRAB TENSILE (lbs)				
WARP	40.7	37.7	39.5	30.4
FILL	37.3	36.5	31.8	22.9
ELONGATION (%)				
WARP	40.5	43.2	39.5	23.7
FILL	41.1	47.7	43.0	39.2
TONGUE TEAR (lbs)				
WARP	4.6	4.0	3.4	3.4
FILL	5.0	4.2	4.1	3.5
% SHRINKAGE (after 5 wash/dry)				
WARP	18.0	11.0		20.0
FILL	15.0	8.0		8.1
TABER ABRASION (% weight loss)	5.0	4.5	4.7	7.2
% WOOL (Chem. extraction)	99.9	99.9		

\*Griege state wool manufactured by Carleton Woolen Mills, Winthrop, Maine.

## EXAMPLE XIX

## Flammability

Flame retardancy in conventionally known fabrics is generally obtained by chemical treatment of high melt point fiber based materials. For example, polyester has a melting point in the range of 480°-500° F. and has wide application in the manufacture of flame retardant materials. Such polyester materials are generally subjected to scouring to provide a contaminant free material which in turn is sealed with a chemical finish.

It has been found that polyester fabrics processed in accordance with the invention exhibit increased flame retardancy. Table XVII sets forth flammability test data for plain polyester fabrics samples hydroenhanced in

accordance with the invention. Sample No. 1 designates control and process tests of enhanced fabric which include five (5) specimen trials. Comparative data is set forth for VISA and TREVIRA brand polyester fabrics.

Flame retardancy standards of NFPA are set forth in Table XVIII. The enhanced fabric exhibits flame retardancy properties which exceed those of the VISA and TREVIRA fabrics. It is believed that these results are a function of scouring aspects of the enhancement process as well as the improved stabilization of the fabric matrix obtained by entanglement of yarns. Further advantage in the invention may be obtained by provision of finishes to the fabric to limit introduction of contaminants to the processed fabric.

TABLE XVII

NFPA 701 - SMALL SCALE POLYESTER FABRICS						
SAMPLE	SPECIMEN	BURN (12+ sec.)		CHAR LENGTH (inches)		COMMENTS
		warp	fill	warp	fill	
No. 1C	1	34.6	76.4	10.0	10.0	Burns with flame
	2	93.7	52.6	10.0	10.0	
CONTROL	3	1.2	43.5	5.7	10.0	Some drips (1-13 sec.)
5.5 osy	4	32.0	13.4	10.0	6.7	
	5	47.0	27.6	10.0	10.0	
AVG. - 5 specimens		41.7	42.7	9.1	9.3	
10 specimens				9.2		
No. 1P	1	3.9	0	4.0	4.5	Melts and

TABLE XVII-continued

NFPA 701 - SMALL SCALE POLYESTER FABRICS						
SAMPLE	SPECIMEN	BURN (12+ sec.)		CHAR LENGTH (inches)		COMMENTS
		warp	fill	warp	fill	
HYDROENHANCED 5.4 osy	2	0	0	5.0	3.8	shrinks from
	3	10.1	23.1	4.2	4.0	flame
	4	0	0	3.6	3.8	Few drips
	5	0	0	5.3	3.0	(1 sec.)
AVG. - 5 specimens		2.8	4.6	4.4	3.8	
10 specimens				4.1		
No. 2	1	0	0	4.3	4.1	Melts and
	2	0	0	3.5	5.3	shrinks
	3	0	0	4.3	6.0	from flame
	4	0	0	4.1	5.8	
VISA*						
FR treated	4	0	0	4.1	5.8	
4.8 osy	5	0	0	5.6	4.6	
AVG. - 5 specimens		0	0	4.4	5.2	
10 specimens				4.2		
No. 3	1	3.8	10.7	4.0	4.9	Burns with
	2	0	6.8	4.8	4.8	flame
	3	0	5.2	6.0	4.2	
	4	0	1.8	5.8	4.6	Some drips
TREVIRA**						
Inherently FR	4	0	2.1	4.9	5.2	(1-13 sec.)
4.2 osy	5	0	5.3	5.1	4.7	
AVG. - 5 specimens		0.8	5.3	5.1	4.7	
10 specimens				5.1		

\*VISA is a trademark of Milliken Research Corporation, Spartanburg, South Carolina.

\*\*TREVIRA is a trademark of Hoechst Celanese Corporation, Charlotte, North Carolina.

The following table from NFPA 701 sets forth the allowable limits for these fabrics.

TABLE XVIII

Permissible Length of Char or Destroyed Material - Small Scale Test		
Weight of Material Being Tested (oz per sq. yd.)	Maximum Average of 10 Specimens (inches)	Maximum Individual for Each Specimen (inches)
Over 10	3.5	4.5
Over 6 and not exceeding 10	4.5	5.5
Not exceeding 6	5.5	6.5

FIG. 19 illustrates an alternative embodiment of the invention apparatus, generally designated 40. The apparatus includes a plurality of drums 42a-d over which a fabric 44 is advanced for enhancement processing. Specifically, the fabric 44 traverses the line in a sinuous path under and over the drums 42 in succession. Rollers 46a and b are provided at opposite ends of the line adjacent drums 42a and d to support the fabric. Any or all of the drums can be rotated by a suitable motor drive (not shown) to advance the fabric on the line.

A plurality of manifolds 48 are provided in groups, FIG. 19 illustrates groups of four, which are respectively spaced from each of the drums 42a-d. An arrangement of manifold groups at 90° intervals on the sinuous fabric path successively positions the manifolds in spaced relation with respect to opposing surfaces of the fabric. Each manifold 48 impinges columnar fluid jets 50, such as water, against the fabric. Fluid supply 52 supplies fluid to the manifolds 48 which is collected in liquid sump 54 during processing for recirculation via line 56 to the manifolds.

The support drums 42 may be porous or non-porous. It will be recognized that advantage is obtained through use of drums which include perforated support surfaces. Open areas in the support surfaces facilitate recirculation of the fluid employed in the enhancement process.

Further advantage is obtained, as previously set forth in discussion of the first embodiment, through use of support surfaces having a fine mesh open area pattern which facilitates fluid passage. Offset arrangement of

the support member orientations, for example at 45° offset orientation as shown in FIG. 2, limits process water streak and weave reed marks in the enhanced fabric.

Enhancement is a function of energy which is imparted to the fabric. Preferred energy levels for enhancement in accordance with the invention are in the range of 0.1 to 2.0 hp-hr/lb. Variables which determine process energy levels include line speed, the amount and velocity of liquid which impinges on the fabric, and fabric weight and characteristics.

Fluid velocity and pressure are determined in part by the characteristics of the fluid orifices, for example, columnar versus fan jet configuration, and arrangement and spacing from the process line. It is a feature of the invention to impinge a curtain of fluid on a process line to impart an energy flux of approximately 0.46 hp-hr/lb to the fabric. Preferred specifications for orifice type and arrangement are set forth in description of the embodiment of FIG. 1. Briefly, orifices 16 are closely spaced with center-to-center spacings of approximately 0.017 inches and are spaced 0.5 inches from the support members. Orifice diameters of 0.005 inches and densities of 60 per manifold inch eject columnar fluid jets which form a uniform fluid curtain.

The following Examples are representative of the results obtained on the process line illustrated in FIG. 20.

#### EXAMPLE XX

A plain woven 100% polyester fabric comprised of friction spun yarns having the following specifications was processed in accordance with the invention: count of 16×10 yarns/in<sup>2</sup>, weight of 8 ounces/yd<sup>2</sup>, an abrasion resistance of 50 cycles (measured by 500 grams of a CS17 abrasion test wheel) and an air permeability of 465 ft<sup>3</sup>/ft<sup>2</sup>/min.

The fabric was processed on a test line to simulate a speed of 300 ft/min. on process apparatus including four drums 42 and eighteen nozzles 16 at a pressure of approximately 1500 psi. Energy output to fabric at these process parameters was approximately 0.46 hp-hr/lb.

Table XIX sets forth control and processed characteristics of the fabric.

TABLE XIX

100% Polyester Friction Spun Fabric		
Fabric Characteristic	Control	Processed
Count (yarns/in. <sup>2</sup> )	16 × 10	17 × 10
Weight (ounces/yd. <sup>2</sup> )	8	8.2
Abrasion resistance (cycles)	50	85
Air permeability (ft <sup>3</sup> /ft <sup>2</sup> /min.)	465	181

## EXAMPLES XXI AND XXII

The process conditions of Example XX were employed to process a plain woven cotton osnaburg and plain woven polyester ring spun fabrics yielding the results set forth in Tables XX and XXI.

TABLE XX

Plain Woven Cotton Osnaburg		
Fabric Characteristic	Control	Processed
Count (yarns/in. <sup>2</sup> )	32 × 26	32 × 32
Abrasion resistance (cycles)	140	344
Air permeability (ft <sup>3</sup> /ft <sup>2</sup> /min.)	710	120

TABLE XXI

Plain Woven Polyester Ring Spun Yarn		
Fabric Characteristic	Control	Processed
Count (yarns/in. <sup>2</sup> )	44 × 28	48 × 32
Abrasion resistance (cycles)	100	225
Air permeability (ft <sup>3</sup> /ft <sup>2</sup> /min.)	252	63

Fabrics processed in Examples XX-XXI are characterized by a substantial reduction in air permeability and increase in abrasion resistance. Process energy levels in these Examples were approximately 0.46 hp-hr/lb. It has been discovered that there is a correlation between process energy and enhancement. Increased energy levels yield optimum enhancement effects.

The foregoing Examples illustrate applications of the hydroenhancing process of the invention for upgrading the quality and physical properties of single ply woven and knit fabrics.

In an alternative application of the hydroenhancing process of the invention, fabric strata are hydrobonded into integral composite fabric. FIG. 20 illustrates a composite flannel fabric 60 including fabric layers 62, 64. Hydrobonding of the layers is effected by first napping opposing surfaces 62a, 64a of each of the layers to raise surface fibers. The opposing surfaces 62a, 64a are then arranged in overlying relation and processed on the production line of the invention. See FIGS. 1 and 16. Enhancement of the layers 62, 64 effects entanglement of fibers in the napped surfaces and bonding of the layers to form an integral composite fabric 60. Exterior surfaces 62b, 64b are also enhanced in the process yielding improvements in cover and quality in the composite fabric.

Napped surfaces 62a, 62b are provided by use of conventional mechanical napping apparatus. Such apparatus include cylinders covered with metal points or teasel burrs which abrade fabric surfaces.

Advantageously, composite fabric 60 is manufactured without requirement of conventional laminating adhesives. As a result, the composite fabric breathes and has improved tactile characteristics than obtained in prior art laminated composites. It will be recognized that

such composite fabrics have diverse applications in fields such as apparel and footwear.

Advantageous results may also be obtained by hydro-enhancing a single strata napped fabric. Entanglement of raised fibers in a napped fabric surface obtained in the invention process yield a superior fabric finish.

FIGS. 21A and B illustrate a composite nonwoven-woven composite fabric in accordance with a further embodiment of the invention. The fabric composite 70 includes a carded nonwoven and woven layers 72, 74 which are arranged in opposing relation and hydrobonded employing enhancement processing. Hydrobonding of the layers and entanglement of the carded nonwoven layer 72 is effected in a one step fluid treatment process. Enhancement of the bonded composite yields a fabric having improved cover and finish. Such nonwoven-woven composite materials have application, among others, for use as interliner materials in textile products.

In another embodiment of the invention, woven or knit fabrics are provided which comprise wrap spun yarns having a fibrous sliver core and water soluble outer sheath components. Enhancement processing effects wash-out of the soluble sheath and entanglement of sliver core fibrous material to yield a stabilized fabric. Wrap spun yarns impart structural integrity to the fabric useful to facilitate weaving of yarns into a stable material for enhancement processing. Enhancement of the fabric and wash-out of the wrap yields a delicate fabric of superior structural integrity. In a preferred application the fabric yarns include a cotton fiber sliver core having a PVA filament wrap, and both top and bottom surfaces of the fabric are subjected to hydraulic enhancement.

Optimum enhancement (in single and multi-ply fabrics) is a function of energy. Preferred results are obtained at energy levels of approximately 0.5 hp-hr/lb. Energy requirements will of course vary for different fabrics as will process conditions required to achieve optimum energy levels. In general, process speeds, nozzle configuration and spacing may be varied to obtain preferred process energy levels.

Enhanced fabrics of the invention are preferably fabricated of yarns including fibers having deniers and lengths, respectively, in the ranges of 0.3 to 10.0 and 0.5 to 6.0 inches, and yarn counts of 0.5 s to 80 s. Optimum enhancement is obtained in fabrics having fiber deniers in the range of 0.5 to 6, staple fibers of 0.5 to 6.0 inches, and yarn counts in the range of 0.5 s to 50 s. Preferred yarn spinning systems employed in the invention fabrics include cotton spun, wrap spun and wool spun. Experimentation indicates that preferred enhancement results are obtained in fabrics including low denier, short lengths fibers, and loosely twisted yarns.

The invention advances the art by recognizing that superior fabric enhancement can be obtained under controlled process conditions and energy levels. Heretofore, the art has not recognized the advantages and the extent to which hydroenhancement can be employed to upgrade fabric quality. It is submitted that the results achieved in the invention reflect a substantial and surprising contribution to the art.

Numerous modifications are possible in light of the above disclosure. For example, although the preferred process and apparatus employ fluid pervious support members, non-porous support members are within the scope of the invention. Similarly, FIGS. 1 and 20 respectively illustrate two and four stage enhancement

process lines. System configurations which include one or more modules having flat, drum or other support member configuration may be employed in the invention.

It will be recognized that the process of the invention has wide application for the production of a diversity of enhanced fabrics. Thus, the Examples are not intended to limit the invention.

Finally, although the disclosed enhancement process employs columnar jet orifices to provide a fluid curtain, other apparatus may be employed for this purpose. Attention is directed to the U.S. Pat. No. 4,995,151 to Siegel et al., entitled "Apparatus and Method For Hydropatterning Fabric", dated Feb. 26, 1991, assigned to International Paper Company, assignee of the present case, which discloses a divergent jet fluid entangling apparatus for use in hydropatterning woven and nonwoven textile fabrics.

Therefore, although the invention has been described with reference to certain preferred embodiments, it will be appreciated that other hydroentangling apparatus and processes may be devised, which are nevertheless within the scope and spirit of the invention as defined in the claims appended hereto.

We claim:

1. An enhanced woven or knit textile fabric which comprises: spun and/or spun filament yarns which intersect at cross-over points to define interstitial open areas and a fabric matrix, said yarns being treated with high pressure fluid energy to effect entanglement thereof in said interstitial open areas, wherein said fluid treatment effects stabilization of said fabric matrix, such that the enhanced woven or knit textile fabric exhibits improved shrink resistance, surface durability, and material absorption and adsorption characteristics.

2. An enhanced woven or knit textile fabric according to claim 1, wherein the fabric includes wool fibers, and the stabilization provides a fabric which is shrink resistant and washable.

3. An enhanced woven or knit textile fabric according to claim 2, wherein the fabric further comprises a second textile fiber.

4. An enhanced woven or knit textile fabric according to claim 3, wherein said textile fiber is polyester.

5. An enhanced woven or knit textile fabric according to claim 1, wherein said fabric includes polyester, and said fluid treatment imparts flame resistance to the fabric.

6. An enhanced woven or knit textile fabric according to claim 1, wherein the fabric includes a napped surface finish having raised surface fibers, said napped finish being subjected to said fluid treatment said fluid treatment entangling said raised fibers and providing a fabric having improved structural integrity and a high loft finish.

7. An enhanced woven or knit textile fabric according to claim 1, wherein the fabric includes wrap spun yarn, said yarn having a sliver core of a first fibrous component, and an outer sheath wrap of a water soluble yarn, said wrap yarn imparting structural integrity to the fabric for textile weaving or knit fabrication, said fluid treatment effecting wash-out of said soluble sheath to provide a stabilized fabric of said first fibrous component having structural integrity.

8. An enhanced woven or knit textile fabric according to claim 7, wherein said sliver core includes cotton fibers, and said outer sheath wrap includes filament

fibers selected from the group consisting of polyester and nylon.

9. An enhanced woven or knit textile fabric according to claim 1, wherein said fabric includes wool fibers, a felt and matted finish is imparted to the fabric by hot water treatment, and said fluid entanglement treatment effects interlocking and stabilization of said wool fibers.

10. An enhanced woven or knit textile fabric according to claim 9, wherein said fabric further comprises a second textile fiber.

11. An enhanced woven or knit textile and nonwoven fabric composite comprising: a fabric layer which includes spun and/or spun filament yarns in a structured pattern of yarns which intersect at cross-over points to define interstitial open areas, and a nonwoven layer which includes staple fibers, said fabric and nonwoven layers being arranged in opposing and congruent relation and bonded into an integral composite by treatment with high-pressure fluid energy, wherein said spun and/or spun filament yarns are entangled within said interstitial open areas and said spun and/or spun filament yarns are also entangled with said staple fibers.

12. An enhanced composite fabric according to claim 11, wherein said nonwoven layer comprises a carded web of staple fibers.

13. A method for hydrobonding woven or knit fabric and nonwoven material layers to form a composite textile fabric, the fabric layer including spun and/or spun filament yarns in a structured pattern which intersect at crossover points to define interstitial open areas, the nonwoven layer including staple fibers, the method comprising the steps of:

arranging said fabric and nonwoven layers in opposing and overlying layered relation, supporting the layered fabric on a support member, and

traversing one side of said layered fabric with a first continuous curtain of fluid for sufficient duration to entangle said spun and/or spun filament yarns in said interstitial open areas and also entangle said staple fibers and spun and/or spun filament yarns, said curtain of fluid impacting the fabric with an energy in the range 0.1 and 2.0 hp-hr/lb.

14. The method of claim 13, wherein said fluid curtain is provided by columnar fluid jet orifices having a diameter of approximately 0.005 inches and center-to-center spacing of approximately 0.017 inches, said fluid curtain impinging the fabric with fluids at a pressure of approximately 1500 psi.

15. The method of claim 14, wherein said support member includes a pattern of closely spaced fluid pervious open areas aligned in a first direction to effect fluid passage through said support member.

16. The method of claim 14, comprising the further steps of:

supporting said layered fabric on a second support member, and

traversing the other side of said layered fabric in a second entanglement stage with a second continuous fluid curtain to effect a uniform composite fabric bond and finish,

said second entanglement stage impacting the layered fabric with an energy in the range 0.1 and 2.0 hp-hr/lb.

17. The method of claim 16, wherein:

said first and second fluid curtains are provided by columnar fluid jets having a diameter of approximately 0.005 inches and center-to-center spacing of

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approximately 0.017 inches, said fluid jets impinging the fabric with fluids at pressure of approximately 1500 psi,  
 said first and second support members each include a pattern of closely spaced fluid pervious open areas, respectively aligned in first and second directions, said open areas being dimensioned to effect fluid passage through said support members without imparting a patterned effect to the fabric.

18. A method for enhancing and finishing textile fabrics including spun wool yarns in a structured woven or knit pattern including yarns which intersect at cross-over points, the method comprising the steps of:  
 felting the fabric by application of hot water treatments to form a matted and integrated fabric finish, supporting the fabric on a first support member, and traversing a first side of said fabric with a first continuous curtain of fluid for sufficient duration to effect entanglement of said yarns at the cross-over points, thereby enhancing fabric cover and quality,  
 said curtain of fluid impacting the fabric with an energy in the range 0.1 and 2.0 hp-hr/lb.

19. The method of claim 18, wherein said fluid curtain comprises hot water.

20. The method of claim 18, wherein said fluid curtain is provided by columnar fluid jet orifices having a diameter of approximately 0.005 inches, center-to-center spacing of approximate 0.017 inches, and spacing from said first support member of approximately 0.5 inches, said fluid jets impinging the fabric with fluids at a pressure of approximately 1500 psi.

21. The method of claim 20, wherein said support member includes a pattern of closely spaced fluid pervious open areas aligned in a first direction to effect fluid passage through said support member.

22. The method of claim 19, comprising the further steps of:

supporting said enhanced fabric on a second support member, and  
 traversing a second side of said enhanced fabric in a second enhancement stage with a second continuous fluid curtain for sufficient duration to further

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enhance fabric cover and provide a uniform fabric finish,

said second enhancement stage impacting the fabric with an energy in the range 0.1 and 2.0 hp-hr/lb.

23. A method for enhancing and finishing textile fabrics including wrap spun yarns in a structured woven or knit pattern which intersect at cross-over points, the fabric including a sliver core of a first fibrous component, and an outer sheath wrap of a water soluble yarn, the method comprising the steps of:

supporting the fabric on a first support member, and traversing a first side of said fabric with a first continuous curtain of fluid for sufficient duration to effect wash-out of the soluble wrap and entanglement of said yarns at the cross-over points, thereby providing a stabilized core material fabric having integrity and enhanced finish,

said curtain of fluid impacting the fabric with an energy in the range 0.1 and 2.0 hp-hr/lb.

24. The method of claim 23, wherein said fluid curtain is provided by columnar fluid jet orifices having a diameter of approximately 0.005 inches, center-to-center spacing of approximately 0.17 inches, and spacing from said first support member of approximately 0.5 inches, said fluid jets impinging the fabric with fluids at pressure of approximately 1500 psi.

25. The method of claim 24, wherein said support member includes a pattern of closely spaced fluid pervious open areas aligned in a first direction to effect fluid passage through said support member.

26. The method of claim 25, comprising the further steps of:

supporting said enhanced fabric on a second support member, and

traversing a second side of said enhanced fabric in a second enhancement stage with a second continuous fluid curtain for sufficient duration to further enhance fabric cover and provide a uniform fabric finish,

said second enhancement stage impacting the fabric with an energy in the range 0.1 and 2.0 hp-hr/lb.

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US006163943A

**United States Patent** [19]**Johansson et al.**[11] **Patent Number:** **6,163,943**[45] **Date of Patent:** **Dec. 26, 2000**[54] **METHOD OF PRODUCING A NONWOVEN MATERIAL**[75] Inventors: **Bernt Johansson, Molnlycke; Lars Fingal, Gothenburg, both of Sweden**[73] Assignee: **SCA Hygiene Products AB, Gothenburg, Sweden**[21] Appl. No.: **09/328,454**[22] Filed: **Jun. 9, 1999**[30] **Foreign Application Priority Data**

Jun. 9, 1999 [SE] Sweden ..... 9703886

[51] Int. Cl.<sup>7</sup> ..... **D04H 3/02; D04H 1/46**[52] U.S. Cl. .... **28/104; 162/115**[58] Field of Search ..... 28/104, 105, 103,  
28/106, 107, 167; 162/100, 101, 202, 115,  
201, 91, 146, 289, 300, 315, 317, 212;  
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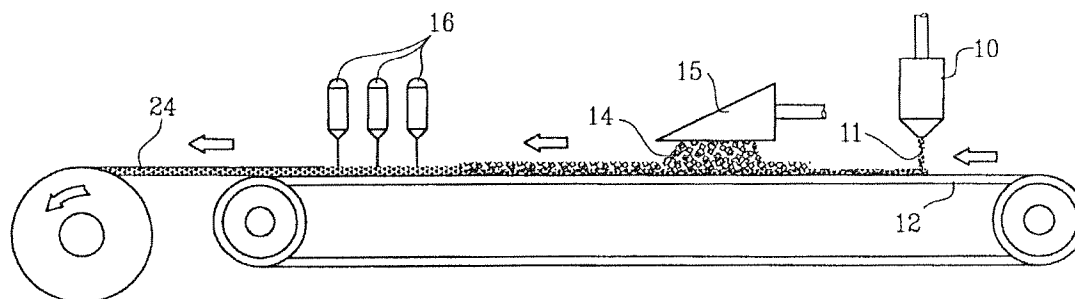
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*Primary Examiner*—Amy B. Vanatta*Attorney, Agent, or Firm*—Burns, Doane, Swecker & Mathis, L.L.P.[57] **ABSTRACT**

Method of producing a nonwoven material by hydroentangling a fiber mixture containing continuous filaments, e.g. meltblown and/or spunbond fibers, and natural fibers and/or synthetic staple fibers. The method is characterized by foamforming a fibrous web (14) of natural fibers and/or synthetic staple fibers and hydroentangling together the foamed fiber dispersion with the continuous filaments (11) for forming a composite material where the continuous filaments are well integrated with the rest of the fibers.

**9 Claims, 8 Drawing Sheets**

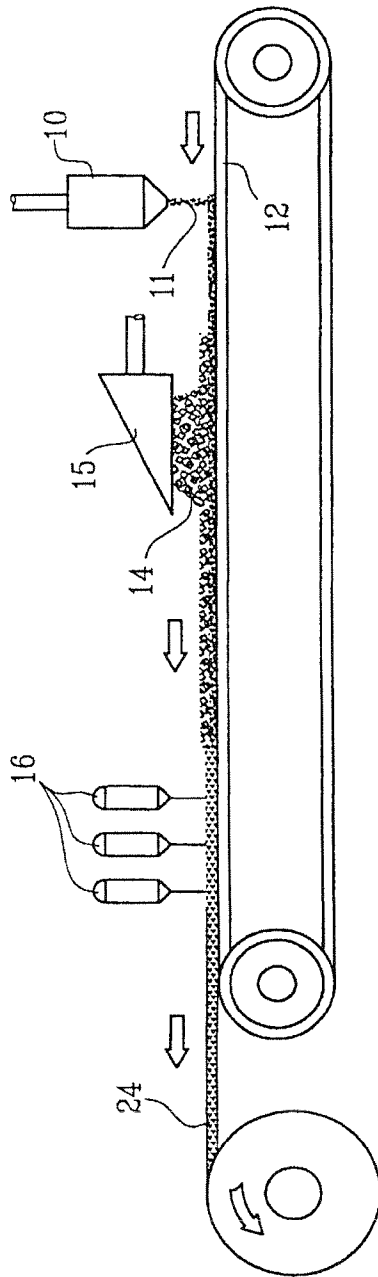


FIG. 1

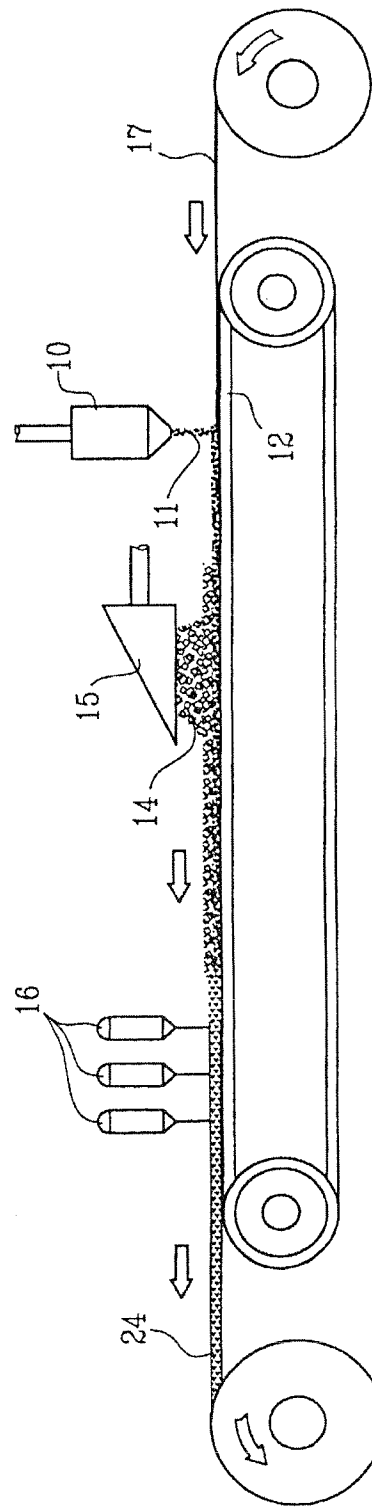


FIG. 2

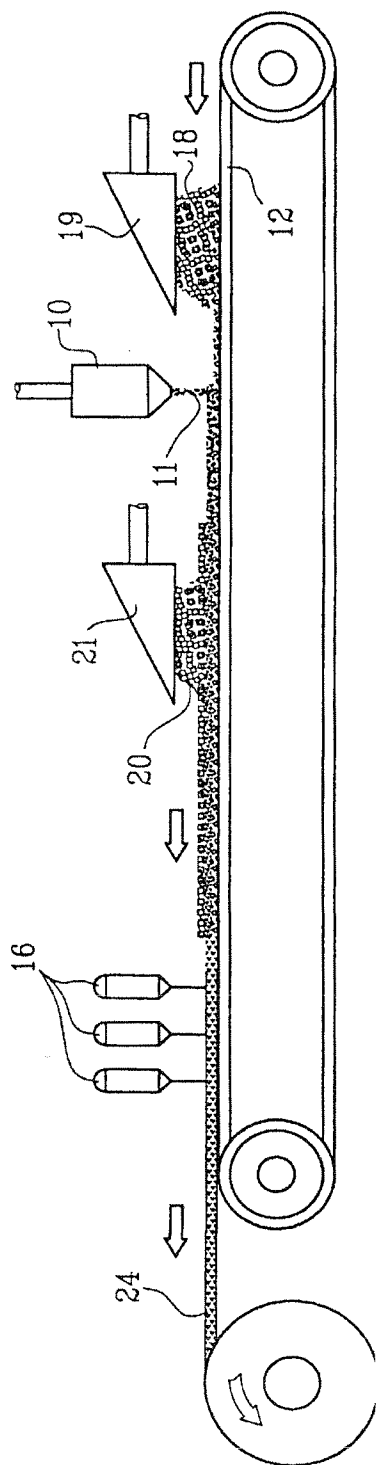


FIG. 3

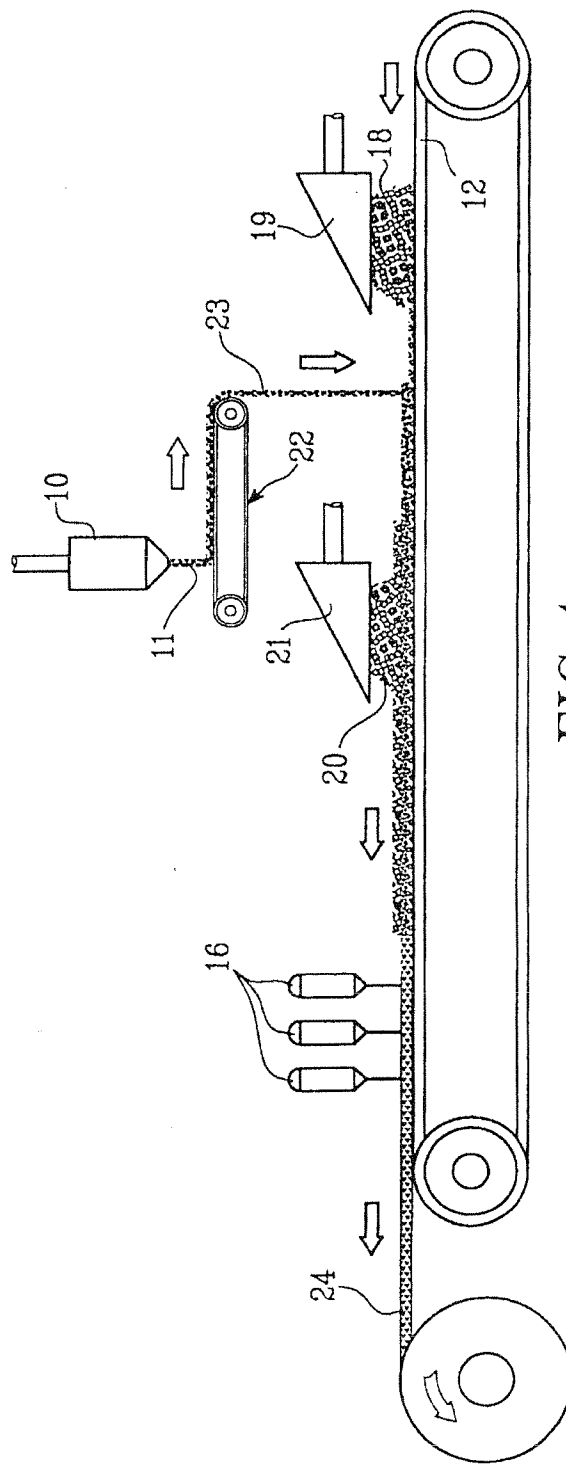


FIG. 4

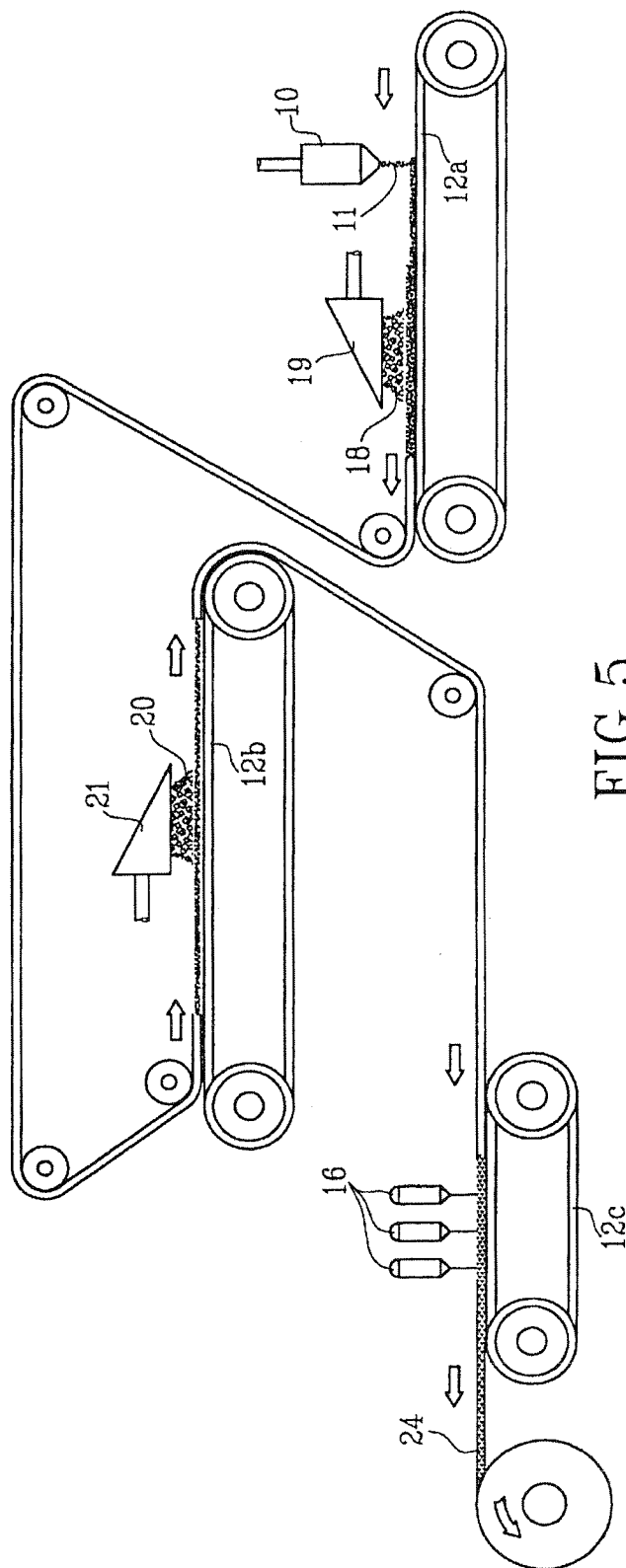


FIG. 5

FIG. 6

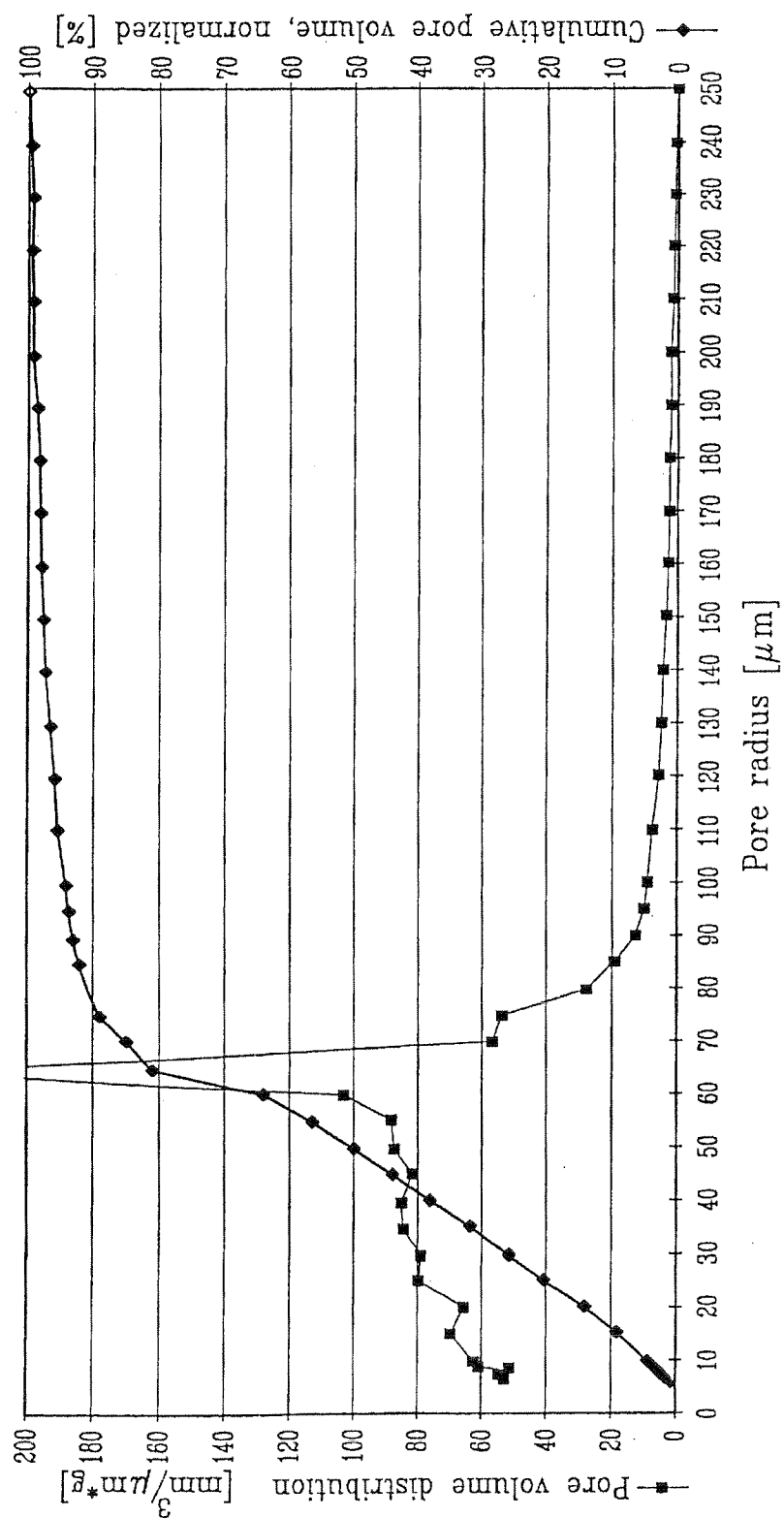


FIG. 7

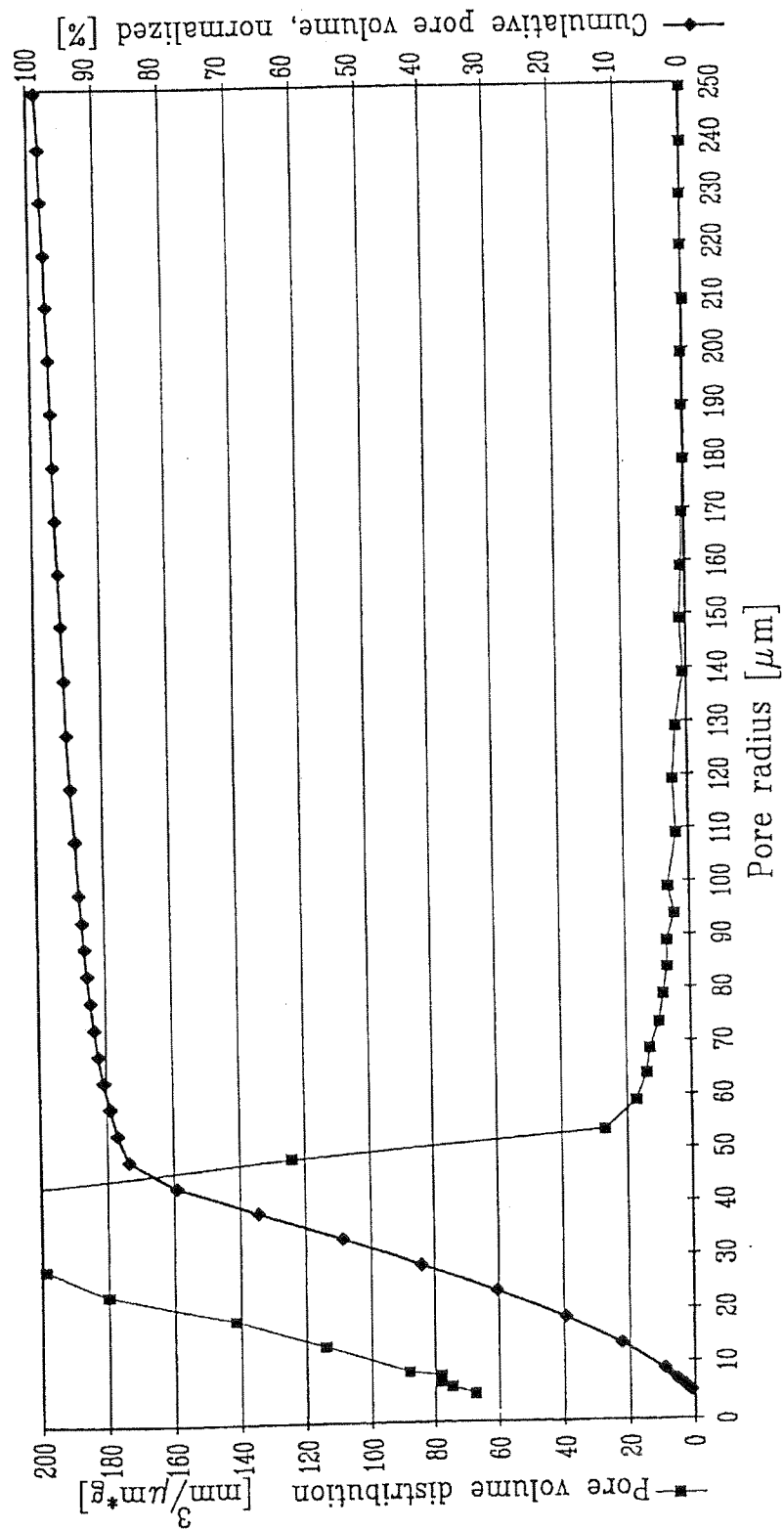
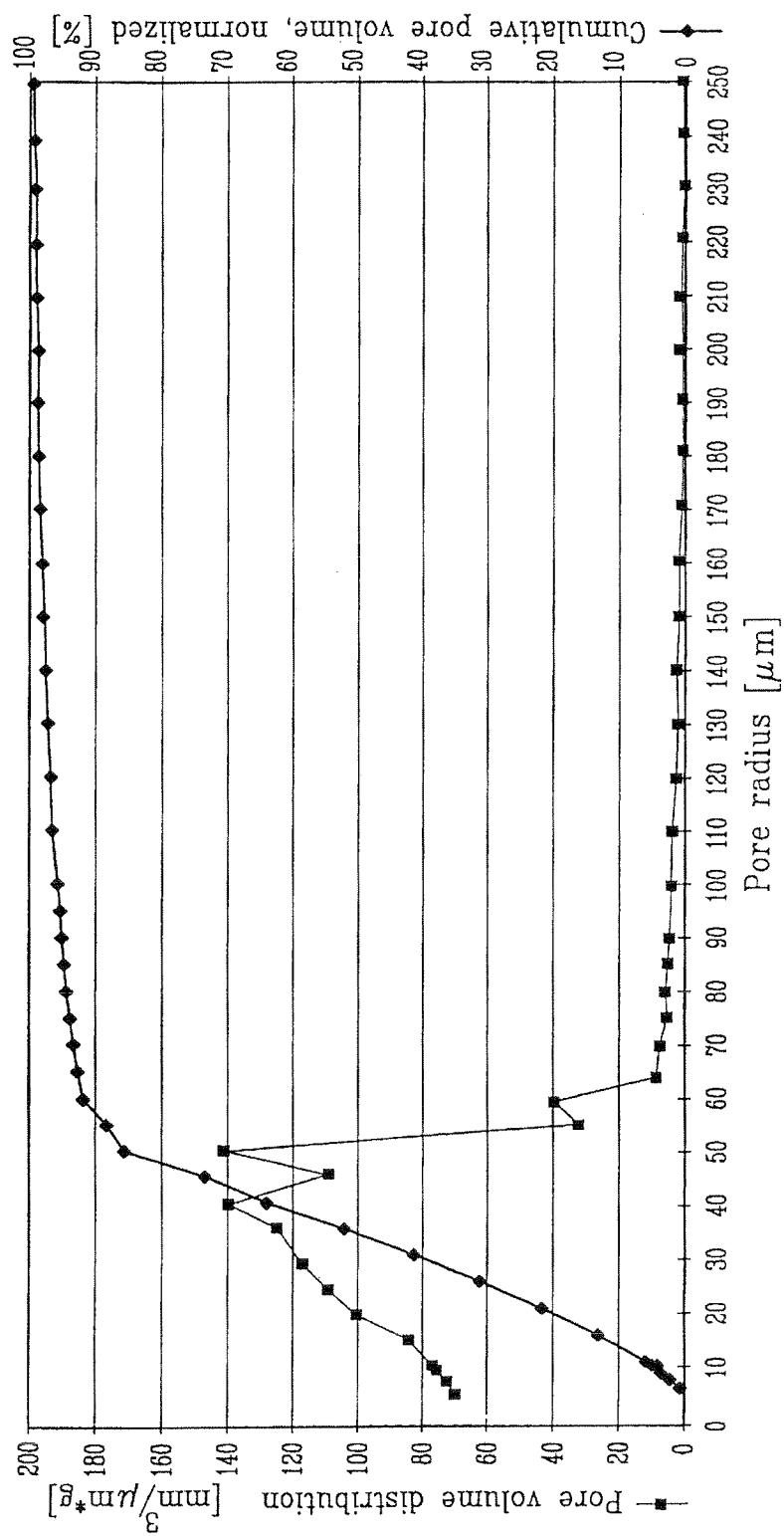


FIG. 8



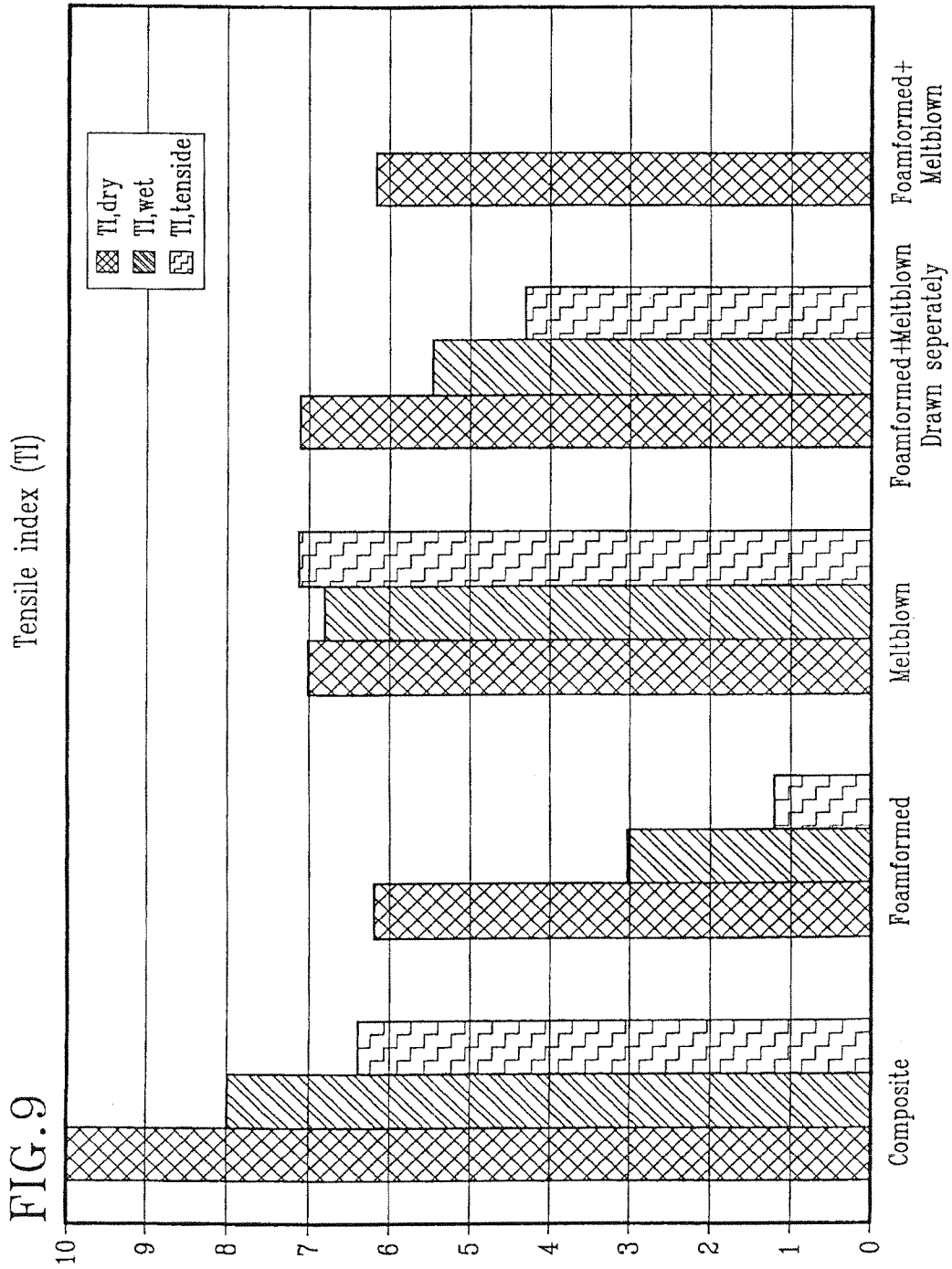




FIG.10

## METHOD OF PRODUCING A NONWOVEN MATERIAL

### BACKGROUND OF THE INVENTION

The present invention refers to a method of producing a nonwoven material by hydroentangling a fiber mixture containing continuous filaments and natural fibers and/or synthetic staple fibers.

Hydroentangling or spunlacing is a technique introduced during the 1970's, see e.g. CA patent no. 841 938. The method involves forming a fiber web which is either drylaid or wetlaid, after which the fibers are entangled by means of very fine water jets under high pressure. Several rows of water jets are directed against the fiber web which is supported by a movable wire. The entangled fiber web is then dried. The fibers that are used in the material can be synthetic or regenerated staple fibers, e.g. polyester, polyamide, polypropylene, rayon or the like, pulp fibers or mixtures of pulp fibers and staple fibers. Spunlace materials can be produced in high quality to a reasonable cost and have a high absorption capacity. They can e.g. be used as wiping material for household or industrial use, as disposable materials in medical care and for hygiene purposes etc.

In WO 96/02701 there is disclosed hydroentangling of a foamformed fibrous web. The fibers included in the fibrous web can be pulp fibers and other natural fibers and synthetic fibers.

Through e.g. EP-B-0 333 211 and EP-B-0 333 228 it is known to hydroentangle a fiber mixture in which one of the fiber components is meltblown fibers. The base material, i.e. the fibrous material which is exerted to hydroentangling, either consists of at least two preformed fibrous layer where one layer is composed of meltblown fibers or of a "coform material" where an essentially homogeneous mixture of meltblown fibers and other fibers is airlaid on a wire and after that is exerted to hydroentangling.

Through EP-A-0 308 320 it is known to bring together a web of continuous filaments with a wetlaid fibrous material containing pulp fibers and staple fibers and hydroentangle together the separately formed fibrous webs to a laminate. In such a material the fibers of the different fibrous webs will not be integrated with each other since the fibers during the hydroentangling are bonded to each other and only have a very limited mobility.

### OBJECT AND MOST IMPORTANT FEATURES OF THE INVENTION

The object of the present invention is to provide a method for producing a hydroentangled nonwoven material of a fibrous mixture of continuous filaments, e.g. in the form of meltblown and/or spunbond fibers and natural fibers and/or synthetic staple fibers, where there is given a high freedom in the choice of fibers and where the continuous filaments are well integrated with the rest of the fibers. This has according to the invention been obtained by foamforming a fibrous web of natural fibers and/or synthetic staple fibers and hydroentangling together the foamed fiber dispersion with the continuous filaments for forming a composite material where the continuous filaments are well integrated with the rest of the fibers.

Through the foamforming there is achieved an improved mixing of the natural and/or synthetic fibers with the synthetic filaments, said mixing effect is reinforced by the hydroentangling, so that a composite material is obtained in which all fiber types are essentially homogeneously mixed

with each other. This is among other things shown by the very high strength properties of the material and by a wide pore volume distribution.

### DESCRIPTION OF THE DRAWINGS

The invention will below be closer described with reference to some embodiments shown in the accompanying drawings.

FIGS. 1-5 show schematically some different embodiments of devices for producing an hydroentangled nonwoven material according to the invention.

FIGS. 6 and 7 show the pore volume distribution in a reference material in the form of a foamformed spunlace material and of a spunlace material consisting only of meltblown fibers.

FIG. 8 shows the pore volume distribution in a composite material according to the invention.

FIG. 9 shows in the form of a staple diagram the tensile strength in dry and wet condition and in a tensile solution for the composite material and for the two base materials included therein.

FIG. 10 is an electron microscope picture of a nonwoven material produced according to the invention.

### DESCRIPTION OF SOME EMBODIMENTS

FIG. 1 shows schematically a device for producing a hydroentangled composite material according to the invention. A gas stream of meltblown fibers is formed according to conventional meltblown technique by means of a meltblown equipment 10, for example of the kind shown in the U.S. Pat. Nos. 3,849,241 or 4,048,364. The method shortly involves that a molten polymer is extruded through a nozzle in very fine streams and converging air streams are directed towards the polymer streams so that they are drawn out into continuous filaments with a very small diameter. The fibers can be microfibers or macrofibers depending on their dimension. Microfibers have a diameter of up to 20  $\mu\text{m}$ , but usually are in the interval between 2 and 12  $\mu\text{m}$  in diameter. Macrofibers have a diameter of over 20  $\mu\text{m}$ , e.g. between 20 and 100  $\mu\text{m}$ .

All thermoplastic polymers can in principle be used for producing meltblown fibers. Examples of useful polymers are polyolefines, such as polyethylene and polypropylene, polyamides, polyesters and polylactides. Copolymers of these polymers may of course also be used, as well as natural polymers with thermoplastic properties.

Spunbond fibers are produced in a slightly different way by extruding a molten polymer, cool it and stretch it to an appropriate diameter. The fiber diameter is usually above 10  $\mu\text{m}$ , e.g. between 10 and 100  $\mu\text{m}$ .

The continuous filaments will in the following be described as meltblown fibers, but it is understood that also other types of continuous filaments, e.g. spunbond fibers, can be used.

According to the embodiment shown in FIG. 1 the meltblown fibers 11 are laid down directly on a wire 12 where they are allowed to form a relatively loose, open web structure in which the fibers are relatively free from each other. This is achieved either by making the distance between the meltblown nozzle and the wire relatively large, so that the filaments are allowed to cool down before they land on the wire 12, at which their stickiness is reduced. Alternatively cooling of the meltblown fibers before they are laid on the wire is achieved in some other way, e.g. by means of spraying with liquid. The basis weight of the formed

meltblown layer should be between 2 and 100 g/m<sup>2</sup> and the bulk between 5 and 15 cm<sup>3</sup>/g.

A foamformed fibrous web 14 from a headbox 15 is laid on top of the meltblown layer. Foamforming means that a fibrous web is formed from a dispersion of fibers in a foamed liquid containing water and a tenside. The foamforming technique is for example described in GB 1,329,409, U.S. Pat. No. 4,443,297 and in WO 96/02701. A foam-formed fibrous web has a very uniform fiber formation. For a more detailed description of the foamforming technique reference is made to the above mentioned documents. Through the intensive foaming effect there will already at this stage occur a mixing of the meltblown fibers with the foamed fiber dispersion. Air bubbles from the intensive turbulent foam that leaves the headbox 15 will penetrate down between and push apart the movable meltblown fibers, so that the somewhat coarser foam-formed fibers will be integrated with the meltblown fibers. Thus after this step there will mainly be an integrated fibrous web and no longer layers of different fibrous webs.

Fibers of many different kinds and in different mixing proportions can be used for making the foamformed fibrous web. Thus there can be used pulp fibers or mixtures of pulp fibers and synthetic fibers, e.g. polyester, polypropylene, rayon, lyocell etc. As an alternative to synthetic fibers natural fibers with a long fiber length can be used, e.g. above 12 mm, such as seed hair fibers, e.g. cotton, kapok and milkweed; leaf fibers e.g. sisal, abaca, pineapple, New Zealand hemp, or bast fibers, e.g. flax, hemp, ramie, jute, kenaf. Varying fiber lengths can be used and by foamforming technique longer fibers can be used than what is possible with conventional wetlaying of fiber webs. Long fibers, ca. 18–30 mm, is an advantage in hydroentangling, since they increase the strength of the material in dry as well as in wet condition. A further advantage with foamforming is that it is possible to produce materials with a lower basis weight than is possible with wetlaying. As a substitute for pulp fibers other natural fibers with a short fiber length can be used, e.g. esparto grass, phalaris arundinacea and straw from crop seed.

The foam is sucked through the wire 12 and down through the web of meltblown fibers laid on the wire, by means of suction boxes (not shown) arranged under the wire. The integrated fibrous web of meltblown fibers and other fibers is hydroentangled while it is still supported by the wire 12 and herewith forms a composite material 24. Possibly the fibrous web can before hydroentangling be transferred to a special entangling wire, which possibly can be patterned in order to form a patterned nonwoven material. The entangling station 16 can include several rows of nozzles from which very fine water jets under very high pressure are directed against the fibrous web to provide an entangling of the fibers.

For a further description of the hydroentangling—or as it also is called the spunlace technique reference is made to e.g. CA patent 841,938.

The meltblown fibers will thus already before the hydroentangling be mixed with and integrated with the fibers in the foamformed fibrous web due to the foaming effect. In the subsequent hydroentangling the different fiber types will be entangled and a composite material is obtained in which all fiber types are substantially homogeneously mixed and integrated with each other. The fine mobile meltblown fibers are easily twisted around and entangled with the other fibers which gives a material with a very high strength. The energy supply needed for the hydroentangling

is relatively low, i.e. the material is easy to entangle. The energy supply at the hydroentangling is appropriately in the interval 50–300 kWh/ton.

The embodiment shown in FIG. 2 differs from the former by the fact that a preformed tissue layer or spunlace material 17, i.e. a hydroentangled nonwoven material, is used, on which the meltblown fibers 11 are laid, after which the foamformed fibrous web 15 is laid on top of the meltblown fibers. The three fibrous layers are mixed due to the foaming effect and are hydroentangled in the entangling station 15 to form a composite material 24.

According to the embodiment shown in FIG. 3 a first foamformed fibrous web 18 is laid on the wire 12 from a first headbox 19, on top of the fibrous web the meltblown fibers 11 are laid and finally a second foamformed fibrous web 20 from a second headbox 21. The fibrous web 18, 11 and 20 formed on top of each other are mixed due to the foaming effect and are then hydroentangled while they are still supported by the wire 12. It is of course also possible only to have the first foamformed fibrous web 18 and the meltblown fibers 11 and hydroentangle together these two layers.

The embodiment according to FIG. 4 differs from the previous by the fact that the meltblown fibers 11 are laid on a separate wire 22 and the preformed meltblown web 23 is fed between the two foam forming stations 18 and 20. It is of course possible to use a correspondingly preformed meltblown web 23 also in the devices shown in FIGS. 1 and 2, where foamforming is made only from the upper side of the meltblown web 23.

According to the embodiment shown in FIG. 5 a layer of meltblown fibers 11 are laid directly on a first wire 12a, after which a first foamformed fibrous web 18 is laid on top of the meltblown layer. The fibrous web is then transferred to a second wire 12b and turned over after which a second foamformed fibrous web 20 is laid on the "meltblown side" from the opposite side thereof. The fibrous web is transferred to an entangling wire 12c and is hydroentangled. For the sake of simplicity the fibrous web in FIG. 5 is not shown along the transporting portions between the forming—and entangling stations.

According to a further alternative embodiment (not shown) the meltblown fibers are fed directly into the foamed fiber dispersion, before or in connection to the formation thereof. The admixture of the meltblown fibers can for example be made in the headbox.

The hydroentangling is preferably made in a known manner from both sides of the fibrous material at which a more homogeneous equilateral material is obtained.

After the hydroentangling the material 24 is dried and wound up. The material is then converted in a known way to a suitable format and is packed.

#### EXAMPLE 1

A foamformed fiber dispersion containing a mixture of 50% pulp fibers of chemical kraft pulp and 50% polyester fibers (1.7 dtex, 19 mm), was laid on a web of meltblown fibers (polyester, 5–8  $\mu$ m) with a basis weight of 42.8 g/m<sup>2</sup> and hydroentangled together therewith, at which a composite material with a basis weight of 85.9 g/m<sup>2</sup> was obtained. The energy supply at the hydroentangling was 78 kWh/ton. The material was hydroentangled from both sides. The tensile strength in dry and wet condition, the elongation and the absorption capacity of the material were measured and the results are shown in the table below. As reference materials a foamformed fibrous web (Ref. 1) and a meltblown web (Ref. 2) corresponding to those used for pro-

ducing the composite material were hydroentangled. The measurement test results for these reference materials both separate and laid together to a double-layer material are presented in table 1 below.

TABLE 1

	Com- posite	Ref. 1	Ref. 2	Ref. 1 + 2 drawn separately	Ref. 1 + 2 drawn together
Basis weight (g/m <sup>2</sup> )	85.9	43.6	42.8	86.4	86.4
Thickness (μm)	564	373	372	745	745
Bulk (cm <sup>3</sup> /g)	6.6	8.6	8.7	8.6	8.6
Tensile stiffness index	102.5	22.2	8.8	—	—
Tensile strength dry, MD (N/m)	1155	540	282	822	644
Tensile strength dry, CD (N/m)	643	136	318	454	438
Tensile index, dry, (Nm/g)	10	6.2	7	7.1	6.1
Elongation MD, %	40	26	75	—	—
Elongation CD, %	68	116	103	—	—
vMD · CD	52	55	88	—	—
Work to rupture MD (J/m <sup>2</sup> )	375	163	175	—	—
Work to rupture CD (J/m <sup>2</sup> )	341	99	256	—	—
Rupture index (J/g)	4.2	2.9	4.9	—	—
Tensile strength wet, MD, (N/m)	878	372	299	671	—
Tensile strength wet, CD, (N/m)	538	45	285	330	—
Tensile index wet (Nm/g)	8	3	6.8	5.4	—
Tensile strength tensile, MD, (N/m)	605	116	281	397	—
Tensile strength tensile, CD, (N/m)	503	22	326	348	—
Tensile index tensile (Nm/g)	6.4	1.2	7.1	4.3	—
Energy supply (kWh/ton)	78	61	77	—	—
Total absorption (g/g)	4.5	6.1	0.2	—	—

As is seen from the above measurement results the tensile strength in dry as well as in wet condition and in tensile solution was considerably higher for the composite material than for the combined reference materials. This indicates that there is a good mixture between the meltblown fibers and the other fibers, which results in an increase of the material strength.

In FIG. 9 there is shown in the form of staple diagram the tensile index in dry and wet condition and in tensile solution for the different materials.

The total absorption of the composite material is almost as good for the reference material 1, i.e. a corresponding spunlace material without admixture of meltblown fibers. On the other hand the absorption was considerably higher than for the reference material 2, i.e. a pure meltblown material.

In FIG. 7 there is shown the pore volume distribution of the foamformed reference material, Ref. 1, in mm<sup>3</sup>/μm.g, and the normalized cumulative pore volume in %. It can be seen that the main part of the pores in the material are in the interval 60–70 μm. In FIG. 7 there is shown the corresponding pore volume distribution for the meltblown material, Ref. 2. The main part of the pores in this material are below 50 μm. From FIG. 8, which shows the pore volume distribution of the composite material according to above, it can be seen that the pore volume distribution for this material is

considerably broader than for the two reference materials. This indicates that there is an effective mixture of fibers in the composite material. A broad pore volume distribution in a fibrous structure improves the absorption—and liquid distribution properties of the material and is thus advantageous.

It can also be seen from the electron microscope picture according to FIG. 10, which shows the composite material produced according to the above described example, that the fibers are well integrated and mixed with each other.

## EXAMPLE 2

A number of hydroentangled materials with different fiber compositions were produced and tested with respect to tensile strength in wet and in dry condition, work to rupture and elongation.

Material 1: A foamformed fiber dispersion containing 100% pulp fibers of chemical kraft pulp, basis weight 20 g/m<sup>2</sup>, was laid on both sides of a very slightly thermobonded, slightly compressed layer of spunbond fibers of polypropylene (PP) 1.21 dtex, basis weight 40 g/m<sup>2</sup>, and was hydroentangled together therewith. The tensile strength of the PP-fibers was 20 cN/tex, the E-modulus was 201 cN/tex and the elongation was 160%. The material was hydroentangled from both sides. The energy supply at the hydroentangling was 57 kWh/ton.

Material 2: A layer of tissue paper of chemical pulp fibers was laid on both sides of a spunbond material, the same as in material A above. The material was hydroentangled from both sides. The energy supply at the hydroentangling was 55 kWh/ton.

Material 3: A foamformed fiber dispersion containing 100% pulp fibers of chemical kraft pulp, basis weight 20 g/m<sup>2</sup>, was laid on both sides of a very slightly thermobonded, slightly compressed layer of spunbond fibers of polyester (PET) 1.45 dtex, basis weight 40 g/m<sup>2</sup>, and was hydroentangled together therewith. The tensile strength of the PET-fibers was 22 cN/tex, the E-modulus was 235 cN/tex and the elongation 76%. The material was hydroentangled from both sides. The energy supply at the hydroentangling was 59 kWh/ton.

Material 4: A layer of tissue paper of pulp fibers (85% chemical pulp and 15% CTMP), with the basis weight 26 g/m<sup>2</sup> was laid on both sides of a spunbond material, the same as in material A above. The material was hydroentangled from both sides. The energy supply at the hydroentangling was 57 kWh/ton.

Material 5: A wetlaid fibrous web containing 50% polyester (PET) fibers (1.7 dtex, 19 mm) and 50% pulp fibers of chemical pulp was hydroentangled with an energy supply of 71 kWh/ton. The basis weight of the material was 87 g/m<sup>2</sup>. The tensile strength of the PET-fibers was 55 cN/tex, the E-modulus was 284 cN/tex and the elongation was 34%.

Material 6: The same as for material 5 above but hydroentangled with a considerably higher energy supply, 301 kWh/ton. The basis weight of the material was 82.6 g/m<sup>2</sup>.

Materials 1 and 3 are composite materials according to the present invention while materials 2 and 4 are laminate materials outside the invention and shall be seen as reference materials. Materials 5 and 6 are conventional hydroentangled materials and should also be seen as references. The energy supply at the hydroentangling of material 5 was of the same order of magnitude as was used for the hydroentangling of materials 1–4, while the energy supply at the hydroentangling of material 6 was considerably higher.

The results of the measurements are shown in table 2 below.

TABLE 2

	Material 1	Material 2	Material 3	Material 4	Material 5	Material 6
Bases weight (g/m <sup>2</sup> )	86.7	93.3	83.6	90.7	87	82.6
Thickness 2kPa (μm)	520	498	415	470	550	463
Bulk 2kPa (cm <sup>3</sup> /g)	6.0	5.3	5.0	5.2	6.3	5.6
Tensile stiffness MD (N/m)	18310	18290	20740	20690	10340	12590
Tensile stiffness CD (N/m)	3250	3531	6546	4688	1756	1709
Tensile stiffness index (Nm/g)	89	86	139	109	49	56.2
Tensile strength dry MD, (N/m)	4024	3746	4192	3893	2885	4674
Tensile strength dry CD, (N/m)	1785	1460	2255	1619	998	1476
Tensile index dry (Nm/g)	31	25	37	28	19.5	31.8
Elongation MD (%)	73	84	80	83	32	34.4
Elongation CD (%)	129	123	100	98	90	87.6
Elongation vMDCD (%)	97	102	89	90	54	55
Work to rupture MD (J/m <sup>2</sup> )	2152	2618	2318	2370	600	906
Work to rupture CD (J/m <sup>2</sup> )	1444	1216	1425	1084	484	695
Work to rupture index (J/g)	20.3	19.1	21.7	17.7	6.2	9.6
Tensile strength MD, wet (N/m)	4401	2603	4028	3574	2360	4275
Tensile strength CD, wet (N/m)	1849	1850	1940	1365	729	1363
Tensile index wet (Nm/g)	32.9	23.5	33.4	24.4	15.1	29.2
Relative strength water (%)	106	94	91	88	77	92
Tensile strength MD tenside (N/m)	3987	1489	3554	2879	874	3258
Tensile strength CD tenside (N/m)	1729	1083	1684	1214	234	985
Tensile index tenside (Nm/g)	30.3	13.6	29.3	20.6	5.2	21.7
Relative strength tenside (%)	98	54	80	74	27	68

The results show higher strength values for the composite materials according to the invention (materials 1 and 3) both compared to the corresponding laminate materials (materials 2 and 4) and compared to the wetlaid reference material (material 5) which had been entangled with an equivalent energy supply. Especially the tensile strength values as well wet, dry as in tenside are considerably higher for the

composite materials according to the invention in comparison with the reference materials. The high strength values verifies that one has a composite material with very well integrated fibers.

For material 6 which had been entangled with a considerably higher energy supply (about 5 times higher) than for the composite materials the tensile strength in dry condition is on the same level as for the composite materials. The relative wet- and tenside strength as well as the work to rupture index are still markedly lower than for the composite materials.

As a further comparison two layers of the spunbond materials used in the above tests were hydroentangled. These material are denoted as materials 6 and 7.

Material 7: Two layers PP-spunbond, 1.21 dtex, each of the basis weight 40 g/m<sup>2</sup>, were hydroentangled with an energy supply of 66 kWh/ton.

Material 8: Two layers PET-spunbond, 1.45 dtex, each of the basis weight 40 g/m<sup>2</sup>, were hydroentangled with an energy supply of 65 kWh/ton.

The measurement results obtained with these materials are shown in table 3 below.

TABLE 3

	Material 7	Material 8
Basis weight (g/m <sup>2</sup> )	78.2	78.4
Thickness 2 kpa (μm)	865	762
Bulk 2kPa (cm <sup>3</sup> /g)	11.1	9.7
Tensile stiffness MD (N/m)	8314	9792
Tensile stiffness CD (N/m)	507	897
Tensile stiffness index (Nm/g)	26	38
Tensile strength MD dry (N/m)	642	798
Tensile strength CD dry (N/m)	183	558
Tensile index dry (Nm/g)	4	9
Elongation MD (%)	9	32
Elongation CD (%)	112	105
Elongation vMDCD (%)	32	58
Work to rupture MD (J/m <sup>2</sup> )	313	604
Work to rupture CD (J/m <sup>2</sup> )	253	508
Work to rupture index (J/g)	3.6	7.1
Tensile strength MD wet (N/m)	210	965
Tensile strength CD wet (N/m)	217	659
Tensile index wet (Nm/g)	2.7	10.2
Relative strength wet (%)	62	120
Tensile strength MD tenside (N/m)	840	713
Tensile strength CD tenside (N/m)	178	292
Tensile index tenside (Nm/g)	4.9	5.8
Relative strength tenside (%)	113	68

As is seen these material have considerably lower strength values in all aspects as compared to the composite materials according to the invention.

The composite material according to the invention has very high strength values at a very low energy supply at the entangling. The reason for this is the homogeneous fiber mixture that has been created, in which the synthetic fibers and the pulp fibers cooperate in the fibrous network so that unusually favourable synergistic effects are achieved. The high values for elongation and work to rupture verifies that there is a composite material with very well integrated fibers and that they cooperate so that the material can take up very large deformations without breaking.

The invention is of course not limited to the embodiments shown in the drawings and described above but can be modified within the scope of the claims.

What is claimed is:

1. A method of producing a nonwoven material by hydro-entangling a fiber mixture of continuous filaments with

natural fibers and/or synthetic staple fibers, the method comprising the steps of:

foamforming a fibrous web of the natural fibers and/or the synthetic staple fibers,

forming a layer of continuous filaments, and

hydroentangling together the foamed fiber dispersion with the continuous filaments to form a composite material where the continuous filaments are well integrated with the rest of the fibers.

2. The method as claimed in claim 1, wherein the foam forming occurs directly on the layer of continuous filaments and further comprising the step of draining the foam formed fibrous web through the filament layer.

3. The method as claimed in claim 1, wherein the layer of continuous filaments is laid directly on top of the fibrous web followed by draining of said fibrous web.

4. The method as claimed in claim 1, wherein the layer of continuous filaments is laid between two foamed fiber dispersions followed by draining said foamed fiber dispersions.

5. The method as claimed in claim 1, wherein the continuous filaments are laid on a preformed layer of tissue or nonwoven.

6. The method as claimed in claim 1, wherein the continuous filaments are fed directly into a foamed fiber suspension before or in connection with formation for forming said foamed fiber dispersion.

7. The method as claimed in claim 1, wherein pulp fibers are present in the foamed fiber dispersion.


8. The method as claimed in claim 1, wherein the continuous filaments are supplied in the form of a relatively loose, open weblike fibrous structure in which the fibers are substantially free from each other, so that they easily can be released from each other and be integrated with the fibers in the foamed fiber dispersion.

9. The method as claimed in claim 1, wherein the continuous filaments are meltblown fibers and/or spunbond fibers.

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(19)		Canadian Intellectual Property Office	Office de la Propriété Intellectuelle du Canada	(11)	<b>CA 841938</b>	(13)	<b>A</b>
		An Agency of Industry Canada	Un organisme d'industrie Canada	(40)	19.05.1970		

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(12)

(21) Application number: **841938D**

(51) Int. Cl:

(22) Date of filing: ..

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(54) **PROCESS FOR PRODUCING A NONWOVEN WEB**

(57) **Abstract:**

*This First Page has been artificially created and is not part of the CIPO Official Publication*

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This invention relates to improved textile-like non-woven fabrics made from paper fibers and to a process for their preparation using liquid streams.

5 Much effort has been expended in an effort to make nonwoven fabrics containing a major proportion of paper fibers. Modified papermaking techniques, using blends of short fibers, reinforcing webs, creping, etc., have afforded some improvement but the products are paper-like rather than cloth-like and are characterized by a lack of durability in use, low abrasion  
10 resistance and a high stiffness or lack of drape. Similarly, dry formation of such structures by either air deposition or carding systems followed by bonding by suitable solvent or thermally activated binders provide structures having poor drape characteristics.

15 In accordance with the present invention, it has been found that nonwoven structures produced by papermaking processes can be treated with high pressure jet streams of water to impart greater toughness, flexibility and extensibility, and a surprising resistance to abrasion and surface  
20 distortion. These improvements are obtained without use of size or adhesives. Fabrics having a high degree of absorbency, which may be much greater than the untreated starting paper, in combination with desirable textile-like drape, soft hand, surface durability and optical covering  
25 power are provided. The products may have a felt-like appearance or may simulate the appearance of a woven fabric.

Embodiments of the invention which consist essentially of paper fibers have a highly entangled fiber structure characterized by a considerable proportion of  
30 fiber segments aligned transversely to the plane of the fabric. The relative fiber positions are evaluated by a "90/0 ratio" optical method, described subsequently, and are quite different from the substantially planar fiber



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positions previously found in paper. This entanglement provides a lower density, which is softer and more absorbent than conventional paper. These embodiments are characterized by a 90/0 ratio of at least 0.33, a density of less than 0.3 gm./cc., a strip tensile strength of at least 0.7 lb./in. per oz./yd.<sup>2</sup>, and an elongation-at-break of at least 10% in all directions. Preferred products have strengths of 1.0 lb./in. per oz./yd.<sup>2</sup> or better. Preferably the elongation-at-break is at least 20%.

Other embodiments contain up to 25% textile staple fibers uniformly distributed through the paper fibers. Stronger products can be provided in this way. The staple fibers are preferably less than 0.75 inch in length (1.9 cm.) so that the fiber mixture can be processed into paper from a slurry on papermaking equipment. Mixtures containing longer staple fibers can be dry-processed into sheet form by random air deposition methods and then treated with the high pressure jet streams of water.

Any of the above embodiments can be assembled with one or more layers of a different type, e.g., a layer of textile fibers or polyurethane foam, and the assembly traversed with high pressure jet streams of liquid to unite the layers into a laminated structure. By assembling an untreated paper layer on top of the second layer, the paper layer can be treated and united with the second layer in a single operation. A preferred embodiment is prepared by depositing textile fibers to form a layer of randomly oriented fibers, entangling the fibers in the layer by treatment with high pressure jet streams to form a fabric which can readily be used in the next step, assembling the fabric with a layer of paper fibers, and traversing the combination with high pressure jet streams of water to form a laminated fabric characterized by a 90/0 ratio of at least 0.33, a density of less than 0.3

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gm./cc., and a strip tensile strength of 1.0 (preferably at least 2.0) lb./in. per oz./yd.<sup>2</sup>. In this embodiment, the paper fibers provide absorbency and resistance to abrasion, the textile fibers provide improved wet and dry strength, and the combination has desirable drape, soft-  
5 ness and covering power.

In forming the laminated embodiments, the layer of textile fibers may consist of any arrangement of the fibers such as woven or knitted fabrics, nonwoven fabrics  
10 or loose webs, mats or batts. Non-woven fabrics of staple or continuous filaments may be bonded by resins, fusion, entanglement or needle punching. Loose webs having fibers disposed in random relationship to one another or in any degree of alignment may be used. Combinations of these  
15 arrays may be desirable for certain uses. By "textile fibers" is meant fibers and plexifilaments of about 0.5 to 10 denier per filament having a length of at least 6 millimeters. The fibers may be natural or synthetically produced, straight or crimped, or possess a latent ability to elongate,  
20 crimp or shrink when heated or given other aftertreatment. In the products of this invention there is a high degree of entangling of the paper fibers with the textile fiber layer, so that the layers are securely held together and perform as a unitary structure in use.

25 The process of this invention will be better understood from the drawing wherein,

Figure 1 is a schematic side elevational view of one form of apparatus for continuous production of embodiments discussed above, and

30 Figure 2 is an exploded isometric view of a jet manifold for use in the above apparatus.

The production of fabric with the above apparatus can be summarized as an improvement in the conventional papermaking process of preparing a stock suspension of fibers

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in water, continuously screening fibers from the stock to form a wet mat, mechanically removing water from the mat to form a sheet, and drying the sheet; wherein the improvement comprises supporting the sheet on an apertured backing member such as a fine mesh screen, jetting water supplied at pressures of 200 to 2000 pounds per square inch (psi.) to form streams having an energy flux of at least 2300 foot-poundals/in.<sup>2</sup> second and a diameter of 3 to 10 mils at the treatment distance, traversing the supported sheet with the streams until a stream energy of 0.05 to 2.0 horsepower-hours per pound of product has been applied, optionally continuing the treatment on a relatively coarse apertured patterning member until a stream energy of 0.05 to 1.0 horsepower-hour per pound of fabric has been applied to form a patterned nonwoven fabric, and drying the product.

The high energy flux streams are preferably formed by jetting water, supplied at a pressure of 750 to 1500 psi., from manifolds having orifices of 3 to 5 mils in diameter arranged in a straight line at right angles to the direction of travel of the sheet being treated. The orifices may be spaced 10 or more per inch, and preferably about 30 to 50 per inch. The treatment with the high energy flux streams can be performed at any time after the sheet has sufficient strength to be transferred to a supporting surface for treatment, but is most economically performed prior to the dryers. When forming a laminated fabric, a preformed layer of textile fibers can be fed continuously under the sheet at any convenient location prior to treatment of the assembly with high energy flux streams.

Referring to Figure 1, the portion designated "Fourdrinier" illustrates the basic features of the wet end of a conventional papermaking machine. A suspension of paper fibers is introduced into stuff box 1, from where it flows at a properly controlled rate into mixing box 2.

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Water is added at inlet 3 to provide a stock of uniform consistency suitable for the grade of paper to be produced.

The stock flows through section 4, where it is screened to remove foreign particles, and into a headbox 5 designed to insure smooth flow and to maintain a uniform mixture.

The stock exits from the headbox as a fluid sheet of uniform thickness through slice 6. The stock is received on

Fourdrinier wire 7, an endless belt of fine mesh wire screen, which travels continuously over breast roll 8 beneath the

slice 6. The wire 7 passes over table rolls 9, around driven couch roll 10 and back to the breast roll. Dandy roll 11 is used to smooth the top surface of the sheet.

Suction boxes 12 assist in draining water from the stock to form a wet paper mat. Suction is also applied in the couch roll to lower the water content of the mat to around 80% so the mat will have sufficient strength for removal from the wire.

The wet paper mat is transferred to felt 13 and is passed between press rolls 14 and 15 to remove additional water from the mat. The water is carried away by the felt, which is guided around rolls 16. More water is removed in a second similar press-section, comprising press rolls 17 and 18, felt 19 and felt rolls 20. The press rolls reduce the water content and form a consolidated paper sheet of adequate strength for the jet treating step of this invention.

The portion of Figure 1 designated "Jet Treating" indicates basic features of an apparatus for treating the paper sheet with high pressure streams of water. Two treatment drums 21 and 22 are shown. These have apertured cylindrical surfaces for supporting the sheet. Suction means similar to a suction couch roll is preferably provided for holding the sheet in place and for removing water during treatment. The optional use of a top screen during part of

the treatment is described subsequently but is not shown in order to keep the drawing simple. Supporting felts may also be desirable but are not shown for purposes of clarity. The cylindrical surface of drum 21 may be a suitably supported, fine mesh wire screen. The surface of drum 22 may be the same or may be a coarse screen for imparting a pattern to the paper sheet.

The paper sheet 23 travels from the presses over rolls 24 and is guided onto the surface of drum 21 by roll 25. The drum rotates clockwise and carries the sheet under a plurality of jet-treatment manifolds 26. Only three are shown for simplicity, but a much larger number may be required for high speed operation. The treated sheet passes from drum 21 over a series of guide rolls 27 to the drum 22. This drum rotates counter-clockwise and the sheet is fed onto it so that the treated face is next to the cylindrical surface of the drum. The sheet is carried beneath a plurality of jet-treatment manifolds 28 to treat the face of the sheet opposite to that previously treated. The treated sheet leaves the drum at guide roll 29, passes to press rolls 30 and 31, and is then guided by a series of rolls 32 to the dryers.

The dryers are of the type conventionally used on the dry end of a papermaking machine. The drums 33 are steam-heated and arranged alternately up and down. The treated sheet 34 follows a serpentine path passing over the upper drums and under the lower drums. Blanket felts 35 and 36 hold the treated sheet tightly against the drums and increase the effectiveness of the dryers. After drying, the sheet proceeds to a conventional windup 37.

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Figure 2 is a perspective view of a portion of one of the jet-treating manifolds 26 or 28 with the parts separated for clarity. Along the central axis of flat metal strip 40 are equally-spaced jet orifices 41. Above this jet strip is a perforated filter plate 42 which has the same outer dimensions as the jet strip but is curved upward along the central axis so that the plate is spaced away from the jet orifices. The plate is perforated with holes 43 which are no larger than the jet orifices so that particles of foreign matter are caught before they can plug the jet orifices. The holes are uniformly arranged along the curved portion of the plate to provide an even flow of liquid to the different jet orifices. A sufficient number of holes to provide about 3.5% open area produces an even flow without excessive pressure drop through the filter plate.

The manifold body 44 has an undercut portion 45, for receiving the filter plate and jet strip, and has a slot 46 which forms a liquid chamber above the filter plate. Fitting 47 connects to the supply of high pressure liquid. A heavy retainer plate 48 is secured to the manifold body by bolts 49 to hold the filter plate and jet strip in place in undercut portion 45 with a liquid-tight seal. A slit 50 extends along the central axis of the retainer plate to expose the jet orifices.

Equipment for supplying high pressure liquid to the manifold is indicated in Figure 1. Used treating liquid is collected in tank 51 and is withdrawn through drain 52. The liquid passes through filter 53 to remove foreign matter and continues through pipe 54 to pump 55. A multiple-piston, positive-displacement pump powered by

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an electric motor 56 is preferred, although other types of pumps can be used. A pulsation dampener 57 is provided in high pressure pump line 58. The high pressure liquid flows from the dampener to a second filter 59 designed to remove  
5 any remaining particles of material large enough to plug the jet orifices. A pleated woven screen which will remove any particles larger than 25 microns in size is preferred. The filtered liquid then flows into feed manifold 60 which supplies the jet manifolds. Conventional pressure  
10 control and pressure relief valves should be provided for regulating the pressure of individual jet manifolds with safety.

The products of this invention can be prepared from any of the fibers which have previously been used in  
15 papermaking. The term "paper fibers" is used herein with reference to fibers having an average length of up to about 4 millimeters, and includes wood pulp, cotton linters and other natural cellulosic fibers, regenerated cellulose, chemically modified cellulosic fibers, synthetic polymer  
20 fibrids and very short plexifilament fibers.

For obtaining maximum strength a long fiber wood pulp species (such as kraft), which has been highly refined, is preferred. Excessive beating during refining reduces the maximum tear strength.

25 For attaining maximum drape and conformability a short fiber pulp (such as hard wood pulp) should be used. It may be desirable for some products to use a blend of several types of wood pulp to optimize physical and aesthetic properties.

30 Due to the nature of the cellulosic fibers, a varied degree of fibrillation of these fibers occurs during

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the hydraulic treatment apart from any previous pulp treatments or linter refining. Such fibrillation further increases the response to continued hydraulic treatment and contributes to such properties as tensile strength and  
5 covering power.

Preferably a finely apertured backing member is used as a support during the jet treatment. It may consist of a perforated plate, sheet, woven screen, honeycomb or the like made of any suitable material which is not susceptible to attack by the fluid streams. Plain woven wire  
10 screens have been found to be satisfactory. Preferably these will contain from 60 to 200 mesh per inch (per 2.54 cm.). The use of coarser screens affords an increased loss of the small paper fibers and increased problems in  
15 reusing the spent wash liquid.

Unless stated to the contrary in the examples, the orifices remain stationary. This produces a fine pattern of very shallow grooves and furrows on the top of the composite web facing the orifices. This effect is reduced  
20 when the orifices are oscillated or when the spacing between orifices is decreased.

It may be desirable to reverse the composite web on the support screen so that the original top layer of paper-making fibers faces the screen for a finishing step.  
25 This is termed "flipping". A relatively coarse screen can be used for such a finishing step when the fiber structure has been given sufficient integrity in the first treatment. A patterned structure resembling a conventional woven fabric can be produced in this manner. A suitable patterning member  
30 may be any screen, perforated or grooved plate which by reason of its apertures and/or surface contours influences

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the movement of fibers into a pattern in response to the fluid streams. Included are screens of about 10 to about 30 mesh per inch and perforated plates having less than 250 openings per square inch. The patterning member may  
5 have a planar or nonplanar surface or a combination of the two types.

In order to obtain the products of the present invention, the paper fibers must be treated with streams of a non-compressible fluid at a sufficiently high energy  
10 flux and for a sufficient amount of treatment to produce a highly entangled fiber structure. The energy flux of a stream in foot-pounds/in.<sup>2</sup> second is  $77 \text{ PG/A}$ , where:

$P$  = the liquid pressure in the manifold in psi.,

$G$  = the volumetric flow of the stream in  
15 cu.ft./minute, and

$A$  = the cross-sectional area of the stream (in.<sup>2</sup>) just prior to impact against the web being treated.

The cross-sectional area ( $A$ ) can be estimated from photographs of the stream with the web removed, or it can be  
20 measured with micrometer probes. The energy flux will be satisfactory when  $P$  is from 200 to 2000 psi., the orifice diameter of the stream is from 2 to 7 mils and the diameter of the stream is from 3 to 10 mils just prior to impact with the web. The orifices used in the subsequent examples  
25 produce streams having over one million energy flux at the pressures shown.

The amount of treatment must be sufficient and is measured by the energy expended per pound of treated product. The energy ( $E_1$ ) expended during one passage un-  
30 der a manifold in the preparation of a given nonwoven

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fabric, in horsepower-hours per pound of fabric, may be calculated from the formula:

$$E_1 = 0.125 (YPG/sb)$$

where: Y = number of orifices per linear inch of manifold,  
5 P = pressure of liquid in the manifold in psig.,  
G = volumetric flow in cu.ft./min./orifice,  
s = speed of passage of the web under the streams,  
in ft./min., and  
b = the weight of the fabric produced, in  
10 oz./yd.<sup>2</sup>.

The total amount of energy expended in treating the web is the sum of the individual energy values for each pass under each manifold. Six manifolds are shown in Figure 1 but a much larger number will normally be used in high speed  
15 operation. From the formula it will be seen that increasing the speed of passage under a manifold decreases the energy ( $E_1$ ) by a proportional amount. The total energy expended per pound of product can be increased by using more manifolds to offset the decrease in energy per manifold.  
20 fold. The products of this invention are made by the use of a total energy ranging from 0.05 to about 2 HP-hrs./lb. (0.07 to 2.8 Calorie/gram).

The fabrics prepared in accordance with the present invention are stable, coherent, strong and ready for  
25 fabric use. If desired, they may be dyed, printed, heat-treated, or otherwise subjected to conventional fabric processing. Thus, for example, they may be treated with resins, binders, sizes, finishes and the like, surface-coated and/or pressed, embossed, or laminated with other  
30 materials, such as foils, films or the like.

The products of the present invention have many applications. Thus, they may be employed in the same uses.

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as are conventional woven or knitted fabrics. Typical applications include apparel, linings, home furnishings, towels, upholstery and other decorative materials, padding and/or insulating materials, covering materials and the like. They may be laminated to similar sheets or to different materials.

#### Tests for Evaluating Physical Properties

In the examples, the tensile properties are measured on an Instron tester at 70°F. and 65% relative humidity. Strip tensile strength is determined for a sample 0.5-inch wide, using a 2-inch sample length and elongating at 50% per minute and reported to the nearest 0.1 unit. The 5% secant modulus (termed "modulus") is determined by A.S.T.M. Standards E6-61, part 10, page 1836 and reported as the nearest whole number. Opacity is determined by T.A.P.P.I. Test T425M-60. Density is calculated from thickness measured with Ames thickness gauges, using a pressure of 4.3 psi. (300 g./cm.<sup>2</sup>) and the fabric weight.

Abrasion resistance is determined using the Tester of the Custom Scientific Co. of Kearney, N.J. (Model CS-149-005) in which a horizontal Silicon Carbide disc (No. 7K disc) rotates on a vertical axis at about 1 revolution/second. A fabric sample is mounted over a resilient backing on a disc parallel to the abrasive disc and attached to a freely rotating vertical shaft that is about one inch off center from the shaft of the abrasive disc. The sample holder is loaded to a total weight of 1000 g. which presses a 1.25-inch diameter portion of the fabric against the abrasive disc. The test is run until failure, by a hole formation, and the time in minutes reported as "abrasion resistance". At 5 minute intervals

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during the test, pills or loose debris are blown off the disc so that such material will not ride under the abrading surface and interfere with the test. Unless otherwise stated the results are given for the paper-making fiber  
5 face of the product.

The products of this invention possess a soft drape characteristic of woven fabrics. One measure of this is a normalized-for-weight drape flex value of no more than the value of  $3.0 (\text{fabric weight}/2.0)^{2/3}$ . These values  
10 are 2.5 and 3.9 for fabric weights of 1.5 and 3.0 oz./yd.<sup>2</sup> as compared to values of 4.1 and 4.8 for paper towels and reinforced paper products having these respective weights. Drape flex or bending length is determined by using a sample 1 inch wide and 6 inches long and moving it slowly  
15 in a direction parallel to its long dimension so that its end projects from the edge of a horizontal surface. The length of the overhang is measured when the tip of the sample is depressed under its own weight to the point where the line joining the tip to the edge of the platform  
20 makes an angle of  $41.5^\circ$  with the horizontal. One-half of this length is the bending length of the specimen, reported in centimeters.

#### Evaluation of Relative Fiber Positions

The relative fiber positions in papers or fabrics  
25 are evaluated by passing light through microtomed sections of these materials. First, a sample of the fabric or paper is embedded in a clear plastic of index of refraction at  $6328 \text{ \AA}$  differing by at least 0.01 from the index of refraction of the fibers in the sample. An axis is fixed arbitrarily on the sample face and a second axis  $90^\circ$  to the  
30

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first is then drawn. Sixty consecutive cross-sections are then cut along each axis. The sections are 30 microns thick, 4 mm. wide and 10 mm. long. Out of each group of sixty, the first and every sixth section thereafter are  
5 kept and the remainder discarded. The ten retained are glued between two glass slides with the same plastic in which the samples are embedded.

The scanning apparatus consists of:

- 10 (1) a source of a collimated, circularly polarized beam of 6328 Å wave length light which is used to illuminate a .8 x 6 mm. area of sample section. A typical source is a helium-neon laser operating in the TEM<sub>00</sub> mode, equipped with a quarter-wave plate. The more uniform the light intensity over the .8 x 6 mm.  
15 area, the more accurately the relative length can be measured;
- (2) a lens;
- (3) a thin opaque plate with a narrow slit which is partially blocked by a relatively wide opaque blocking patch perpendicular to the slit;  
20
- (4) a second lens similar to the first;
- (5) a photocell with a .8 x 6 mm. aperture;
- (6) a recorder to pick up the signal from the photocell;  
and
- 25 (7) a projection lens.

The focal length of the lenses, the slit length and width, and blocking patch size are in proper proportion such that the photocell signal from a straight fiber segment goes from maximum to 1/2 value when the fiber is  
30 rotated  $9 \pm 3^\circ$  from the angle at which the maximum signal occurs.

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To effect the measurement, a cross-section is placed one focal length from one of the lenses. One focal length on the other side of that lens is placed the thin plate with the slit. That location is also one focal  
5 length from the second lens which is located on the other side of the slit. On the other side of the second lens and one focal length from it is placed the (removable) photocell. The projection lens is placed behind the photocell position.

10 The light beam is thus directed through a cross-section, first lens, on the blocking patch over the slit (and an equal distance from the edges of the slit), through the second lens and to the photocell or projection lens.

15 The section image is formed on a screen by the projection lens and the section is aligned with the sample length perpendicular to the slit with a region containing no fiber segments in the .8 x 6 mm. field. The slit is rotated through 90° and the signal from the photocell is  
20 recorded when the slit makes an angle of 0° and 90° with the width of the sample. The section is then aligned with the center area of the sample in the .8 x 6 mm. field. If the sample is thicker than .8 mm. then the section is placed with one surface of the fabric just within the .8 x 6 mm.  
25 field (regions near the edge of the section are avoided). The signal is recorded with the slit length at an angle of 0° and 90° to the width of the sample. The angles are determined with an accuracy of  $\pm 6^\circ$  and a precision of  $\pm 1^\circ$ . The relative light intensity is determined with an  
30 accuracy of  $\pm 10\%$  and a precision of  $\pm 2\%$ .

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The photocell signal from the sample minus the signal from the clear region is summed at  $0^\circ$  and at  $90^\circ$  for each set of ten sections cut along an axis. The total at  $90^\circ$  is divided by the total at  $0^\circ$ . The smallest value found for the two sets of sections is called the 90/0 ratio. If a sample has a low enough density, the fiber segments in the microtomed sections will be separated from each other and the 90/0 ratio is a measure of the fiber length oriented at  $90^\circ$  to the sample plane, to the fiber length oriented at  $0^\circ$ . If a sample has a high enough density, the fiber segments in the microtomed sections will be compacted and the 90/0 ratio is the ratio of the sample surface area which is oriented at  $90^\circ$  to the sample plane, to the surface area oriented at  $0^\circ$ .

15

EXAMPLE 1

A sheet of dry wood pulp (Buckeye Paper grade wood pulp Pl3) with a dry weight of  $4 \text{ oz./yd.}^2$  ( $135 \text{ g./m.}^2$ ) is supported on a 200 x 200 mesh per inch screen (34% open area) and passed at a speed of 3 ypm (2.7 mpm) under a row of substantially cylindrical, unbroken, vertical jet streams of water. The streams are produced by a row of funnel-shaped orifices spaced 40 per inch (per 2.54 cm.) located in a manifold about 2 cm. above the top of the paper layer. The water enters the cylindrical portion of the orifice 5.0 mils (0.127 mm.) in diameter and about 1 mil (0.025 mm.) long and exits as a stream from the frustro-conical portion which is 11 mils (0.28 mm.) long and has a diameter of about 15 mils (0.38 mm.) at the exit edge of the cone. The following sequence of treatments is used:

30

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<u>Passes</u>	<u>Pressure</u>		<u>Top Screen</u>
	<u>psi.</u>	<u>(kg./cm.<sup>2</sup>)</u>	<u>14 x 18 mesh with about 65% open area</u>
5	2	300 (21)	yes
	2	600 (42)	yes
	2	800 (56)	yes
	2	800 (56)	no with oscillation

This affords a total treatment of 0.8 HP-hrs./lb. of the product (1.1 Cal./g.).

10 Properties of the product are given in Table I.

The product is a nonforaminous, soft, flexible fabric with a felt-like appearance but having a fine pattern of very shallow grooves and furrows on one face.

#### EXAMPLE 2

15 Kraft bleached wood pulp (Weyerhaeuser Pulp Co. - Kraft SG-Sulfate) is opened, beaten in water with a Waring Blendor laboratory stirrer for 15 minutes and made into a sheet. The sheet is supported on a 60 x 60 mesh per inch  
20 twill-weave wire screen (20% open area) and hydraulically entangled by passing at 8 ypm (7.3 mpm) under a row of water jets. The orifices spaced 40/inch (per 2.54 cm.) have a similar design to that of Example 1, the cylindrical portion having a diameter of 3.5 mils (0.089 mm.). The total treatment consists of 1 pass each at 500, 300 and  
25 600 psi. (35, 18 and 42 kg./cm.<sup>2</sup>, respectively) to give a total treatment of about 0.1 HP-hrs. per pound of product (0.2 Cal./g.).

Properties of the product are given in Table I.

30 The product has a fine pattern of very shallow grooves and furrows on one face and a replica of the screen

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pattern on the other face. When viewed against a light, a regular pattern of holes is visible. The product has a soft tactile hand and because of its appearance and drape resembles a textile woven fabric.

5

### EXAMPLE 3

A sheet of the wood pulp of Example 1 of 7.2 oz./yd.<sup>2</sup> dry weight (249 g./m.<sup>2</sup>) is supported on a 100 x 100 mesh per inch screen (34% open area) and passed at 3 ypm (2.7 mpm) under water jets from a row of the orifices of Example 1 spaced 20 per inch (per 2.54 cm.) for the following treatments:

	<u>Passes</u>	<u>Pressure</u>		<u>Top Screen</u>
		<u>psi.</u>	<u>(kg./cm.<sup>2</sup>)</u>	
	2	500	(35)	yes
	2	1000	(70)	yes
15	2	1000	(70)	no

The sample was then flipped and the above sequence repeated to give a total treatment of 0.8 HP-hrs./lb. (1.1 Cal./g.).

The jets were oscillated for the second pass at each pressure. Properties of the product are given in Table I. The product is a nonforaminous, soft, flexible fabric with a felt-like appearance but having a fine pattern of very shallow grooves and furrows on one face.

### EXAMPLE 4

A blend of approximately 20% of rayon staple fibers, 1.25 dpf with a length of 2 inches (5.1 cm.), and 80% of opened wood pulp of Example 2, is formed into a web on a laboratory scale random web former. The resulting web is placed on a 50 x 50 mesh per inch (per 2.54 cm.) screen (20% open area) and hydraulically entangled using the apparatus and speed of Example 2 by the following sequence:

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	<u>Passes</u>	<u>Pressure</u>		<u>Top Screen</u>
		<u>psi.</u>	<u>(kg./cm.<sup>2</sup>)</u>	
	1	300	(21)	yes
	2	600	(42)	no
5	1	700	(49)	no

for a total treatment of about 0.2 HP-hrs./lb. (0.3 Cal./g.).

Properties of the product are given in Table I. The product has a fine pattern of very shallow grooves and furrows on one face and a slight, embossed-like replica of the screen pattern on the other face. When viewed against a light, a regular pattern of small holes is visible.

#### EXAMPLE 5

An aqueous dispersion containing 80% of the wood pulp of Example 1 and 20% 0.25-inch (6.3-mm.) long rayon staple of 1.5 dpf. is used to form a sheet. The sheet is supported on an 80 x 80 mesh per inch (per 2.54 cm.) screen (19% open area) and passed at 3 ypm (2.7 mpm) under a row of water streams from a row of funnel-shaped orifices having a 3.0 mil (0.076 mm.) diameter cylindrical section and spaced 40 per inch (per 2.54 cm.) by the following sequence:

	<u>Passes</u>	<u>Pressure</u>		<u>Top Screen</u>
		<u>psi.</u>	<u>(kg./cm.<sup>2</sup>)</u>	
	2	400	(28)	yes
	2	600	(42)	yes
25	2	800	(56)	yes

The sample was then flipped and the above sequence repeated for a total treatment of about 0.4 HP-hrs./lb. (0.6 Cal./g.).

Properties of the product are given in Table I. The product is a nonforaminous, soft, flexible fabric with a felt-like appearance but having a fine pattern of very shallow grooves and furrows on one face.

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EXAMPLE 6

5 An aqueous dispersion containing 80% of a kraft wood pulp and 20% of 0.375-inch (9.5-mm.) long, 1.5 dpf rayon staple is used to form a sheet. The sheet is supported on a 180 x 180 mesh per inch (per 2.54 cm.) screen (37% open area) and passed at 10 ypm (9.2 mpm) under water streams of the apparatus of Example II by the following procedure:

10	<u>Passes</u>	<u>Pressure</u>		<u>Top Screen</u>	<u>Jets Oscillated</u>
		<u>psi.</u>	<u>(kg./cm.<sup>2</sup>)</u>		
	1	500	(35)	yes	yes
	1	1000	(70)	yes	yes
	1	1000	(70)	no	no

The sample was then flipped and further treated as follows:

15	1	1000	(70)	no	yes
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for a total treatment of about 0.2 HP-hrs./lb. (0.3 Cal./g.) to make product A.

20 The above procedure is repeated substituting 0.75-inch (1.9-cm.) long rayon staple for the shorter rayon above to make product B. A sample of B is then placed on a 20 x 20 mesh per inch (per 2.54 cm.) screen (19% open area) and hydraulically treated following the same general procedure for an additional 0.06 HP-hrs./lb. (0.085 Cal./g.) to yield product C.

25 Products A and B have the appearance of a felt material. Product C more nearly resembles a woven fabric with a pattern of apertures of about 5 - 7 mm. in diameter.

TABLE I

Example	Fabric Weight oz/yd <sup>2</sup> (g./m <sup>2</sup> )	Strip Tensile MD x CD lb/in./oz/yd <sup>2</sup> (g/cm./g./m <sup>2</sup> )	Elongation MD x CD %	Modulus MD x CD lb/in./oz/yd <sup>2</sup> (g/cm./g./m <sup>2</sup> )	90/0 Ratio	Density g/cm <sup>3</sup>	Drape Flex cm MD x CD	Opacity %	Abrasion Resistance minutes
1	2.7 (92)	0.8 (4.2)	37		0.83	0.14			8
2	2.6 (88)	1.0 x 1.2 (5.3 x 6.3)	24 x 23	12 x 11 (64 x 58)	0.42	0.11	3.4	80	2.9
3	5.9 (196)	1.6 (8.5)	52	7 (37)	1.1	0.15	3.6	88	> 110
4	2.6 (88)	2.3 x 1.8 (12 x 9.5)	43 x 55	4 x 4 (21 x 21)	0.38	0.12	3.6 x 3.5	67	5.4
5	5.3 (180)	1.8 (9.5)	43	9 (48)	0.78	0.18	3.6	89	> 35
6A	1.8 (61)	0.9 x 0.9 (4.8 x 4.8)	40 x 30	3 x 7 (16 x 37)	0.48	0.14	2.2 x 2.9	69	4
6B	1.7 (58)	1.2 x 1.2 (6.3 x 6.3)	31 x 36	8 x 7 (42 x 37)	0.45	0.14	2.1 x 1.7	73	1
6C	2.0 (68)	1.1 x 0.9 (5.8 x 4.8)	32 x 32	7 x 5 (37 x 26)	0.63	0.13	1.7 x 1.9	66	-

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EXAMPLE 7

Rayon fibers of 1.56-inch (3.94-cm.) length and 1.5 dpf are made into a web having a weight of 0.7 oz./yd.<sup>2</sup> (24 g./m.<sup>2</sup>) of randomly oriented fibers by an air deposition process using a Rando-Webber machine (made by Curlator Corporation of East Rochester, N.Y.).

The above web is placed on a 60 x 60 mesh screen, covered with a sheet of a commercial saturation paper made of soft wood pulp having a dry weight of 1.9 oz./yd.<sup>2</sup> (64 g./m.<sup>2</sup>) and passed at a speed of 8 ypm (7.3 mpm) under a row of substantially cylindrical, unbroken vertical jet streams of water. The streams are produced by a row of funnel-shaped orifices spaced 40 per inch (per 2.54 cm.) located in a manifold about 2 cm. above the top of the paper layer. The water enters the cylindrical portion of the orifice 3.5 mils (0.089 mm.) in diameter and about 2 mils (0.051 mm.) long and exits as a stream from the frustro-conical portion which is 10 mils (0.25 mm.) long and has a diameter of about 11 mils (0.28 mm.) at the exit edge of the cone. The following sequence of treatments is used:

<u>Passes</u>	<u>Pressure</u>		<u>Top Screen</u>
	<u>psi.</u>	<u>(kg./cm.<sup>2</sup>)</u>	
1	200	(14)	yes
1	600	(42)	yes
1	600	(42)	no
1	800	(56)	no

This affords a total treatment of about 0.1 HP-hrs./lb. of the product (0.2 Cal./g.).

Properties of the product are given in Table II.

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EXAMPLE 8

The procedure of Example 7 is repeated with the exception that the rayon staple web is hydraulically entangled for a total energy of 0.3 HP-hr./lb. at pressures not exceeding 800 psi. (56 kg./cm.<sup>2</sup>) before it is assembled as the bottom side of a composite web. The composite web is hydraulically entangled using the equipment and procedure of Example 7, using 1 pass at 300 psi. (21 kg./cm.<sup>2</sup>) with the top screen and a second pass at 800 psi. (56 kg./cm.<sup>2</sup>) without a top screen for a total treatment of 0.06 HP-hrs./lb. of product (0.085 Cal./g.).

Properties of the product are given in Table II.

EXAMPLE 9

Woven cotton tobacco cloth weighing 0.45 oz./yd.<sup>2</sup> (15 g./m.<sup>2</sup>) is covered with a sheet of a paper (density 0.39 g./cm.<sup>3</sup>) made from a soft wood pulp (Buckeye P13) weighing 1.8 oz./yd.<sup>2</sup> (61 g./m.<sup>2</sup>) and the composite web hydraulically entangled using the equipment and speeds of Example 7 for 1 pass at 500 psi. (35 kg./cm.<sup>2</sup>) with a top screen and 2 passes at 800 psi. (56 kg./cm.<sup>2</sup>) without a top screen for a total treatment of about 0.2 HP-hrs./lb. of product (0.3 Cal./g.).

Properties of the product are given in Table II.

EXAMPLE 10

A urethane foam sheet 0.25-inch (6.3-mm.) thick with a weight of 2.2 oz./yd.<sup>2</sup> (75 g./m.<sup>2</sup>) is covered with 2 sheets of a commercial paper hand towel having a dry weight of 1.45 oz./yd.<sup>2</sup> (49 g./m.<sup>2</sup>) per sheet. The composite web is placed on a 20 x 20 mesh screen and passed

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at 2 ypm (1.8 mpm) under streams of water. The streams are produced by a row of funnel-shaped orifices spaced 40 per inch (per 2.54 cm.) located in a manifold about 2 cm. above the top of the web. The water enters the cylindrical portion of the orifice 5 mils (0.13 mm.) in diameter and about 1 mil (0.025 mm.) long and exits as a stream from the frustro-conical portion which is 11 mils (0.28 mm.) long and has a diameter of about 15 mils (0.38 mm.) at the exit edge of the cone. The sequence of treatment follows:

10	<u>Passes</u>	<u>Pressure</u>		<u>Top Screen</u>
		<u>psi.</u>	<u>(kg./cm.<sup>2</sup>)</u>	
	1	500	(35)	yes
	1	1000	(70)	no
	1	800	(56)	no
15	1	1000	(70)	no

This gives a total treatment of 1.4 HP-hrs./lb. of product, (2 Cal./g.). Properties of the product are given in Table II. The product has a very abrasion resistant surface with fabric-like tactile aesthetics.

20. EXAMPLE 11

The starting layer of textile fibers is a 1.8 oz./yd.<sup>2</sup> (61 g./m.<sup>2</sup>) weight web containing 88% of poly-(ethylene terephthalate) continuous filament of 3 dpf with a potential self-elongation of 8 - 10% and 12% of poly-(ethylene isophthalate/terephthalate) copolymer continuous filaments of 2.3 dpf. The web is prepared by the process of British Patent No. 932,482 and has been compressed at about 100°C. to consolidate the web without fusing the copolymer binder filaments. The web is hydraulically entangled to a strong nonwoven by treatment on a 40 mesh

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(21% open area) screen with streams from the 5 mil diameter orifices of Example 10 for a total of 2.2 HP-hrs./lb. (3.1 Cal./g.).

5 A sheet of kraft paper with a dry weight of 2.7 oz./yd.<sup>2</sup> (92 g./m.<sup>2</sup>) is placed on top of the above entangled web and screen and passed under the above water streams at 2 ypm (1.8 mpm) as follows:

	<u>Passes</u>	<u>Pressure</u>		<u>Top Screen</u>
		<u>psi.</u>	<u>(kg./cm.<sup>2</sup>)</u>	
10	2	300	(21)	yes
	2	600	(42)	yes
	2	1000	(70)	yes
	2	1000	(70)	no

15 This affords a total energy of 1.4 HP-hrs./lb. for the composite structure. The nonwoven fabric is dried and then ironed with a hand iron using "Linen" setting to melt the binding fibers.

20 The product has a remarkable abrasion resistance of over 270 minutes. For comparison, the initial (unentangled) polyester fiber web after bonding by ironing has an abrasion resistance of only 7 minutes.

Properties of the product are given in Table II.

#### EXAMPLE 12

25 High wet modulus rayon (dry tenacity 4.9 gpd, wet tenacity 3.4 gpd) staple of 1.25 dpf and 2-inch (5.1-cm.) length is made into a randomly oriented web of 0.3 oz./yd.<sup>2</sup> (10 g./m.<sup>2</sup>) weight.

30 The above textile fiber web is placed on a 150 x 150 mesh screen, covered with a layer of kraft paper with a dry weight of 1.0 oz./yd.<sup>2</sup> (34 g./m.<sup>2</sup>) and passed at 2 ypm

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(1.8 mpm) under the water streams of the orifices of Example 7 according to the following schedule:

	<u>Passes</u>	<u>Pressure</u>		<u>Top Screen</u>
		<u>psi.</u>	<u>(kg./cm.<sup>2</sup>)</u>	
5	1	400	(28)	yes
	1	500	(35)	no
	web flipped			
	1	500	(35)	no

for a total energy of 0.4 HP-hrs./lb. (0.56 Cal./g.).

- 10           The above non-foraminous web is then placed on a 20 x 20 mesh screen (19% open area) with the paper face up and passed twice under the streams at 500 psi. (35 kg./cm.<sup>2</sup>) with the orifices oscillating for a treatment energy of 0.25 HP-hrs./lb. (0.35 Cal./g.). The product
- 15   is a foraminous nonwoven having a square pattern of apertures about 5-7 mm. in diameter. Properties are given in Table II.

- 20           If one attempts to make the above product directly by doing all of the hydraulic treatment on the coarse screen with the same total energy input, it is found that the product is significantly weaker than above and that a significant amount of paper fibers are washed away.

### EXAMPLE 13

- 25           A randomly oriented web of 0.5 oz./yd.<sup>2</sup> (17 g./m.<sup>2</sup>) weight containing polyester staple of 1.5-inch (3.8-cm.) length and 1.5 dpf is placed on a 60 x 60 mesh screen. It is covered with a sheet of soft wood pulp paper having a dry weight of 1.6 oz./yd.<sup>2</sup> (54 g./m.<sup>2</sup>) and hydraulically entangled using the water streams and

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sheet velocity of Example 7, by the following sequence:

	<u>Passes</u>	<u>Pressure</u>		<u>Top screen</u>
		<u>psi.</u>	<u>(kg./cm.<sup>2</sup>)</u>	
5	1	500	(35)	yes
	1	600	(42)	no
	1	300	(21)	yes
	1	600	(42)	no

The total treatment energy is 0.14 HP-hrs./lb. (0.2 Cal./g.). Properties of the product are given in  
10 Table II.

EXAMPLE 14

(a) A random web of the rayon fibers of Example 12, with a weight of 0.5 oz./yd.<sup>2</sup> (17 g./m.<sup>2</sup>), is placed on a 150 x 150 mesh screen (37% open area) and covered with a  
15 sheet of kraft paper tensile strength of 4.2 lb./in. per oz./yd.<sup>2</sup> (22 g./cm. per g./m.<sup>2</sup>) and 3% elongation<sup>7</sup> with a dry weight of 2.0 oz./yd.<sup>2</sup> (68 g./m.<sup>2</sup>) and passed at 10 ypm (9.1 mpm) under water streams from the orifices of  
Example 7 as follows:

20	<u>Passes</u>	<u>Pressure</u>		<u>Top Screen</u>
		<u>psi.</u>	<u>(kg./cm.<sup>2</sup>)</u>	
	1	1200	(84)	yes
	2	1500	(105)	no
	web flipped			
25	1	1500	(105)	no

for a total energy of about 0.3 HP-hrs./lb. (0.5 Cal./g.). The properties of the product are reported in Table II and include an excellent value for abrasion resistance of 30 minutes. The product is laundered and tumble-dried in a  
30 conventional household combination machine, using a cotton

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setting, without noticeable effect on its appearance or utility as a fabric.

(b) The above procedure is repeated with the substitution of a sheet of kraft paper with a dry weight of 1 oz./yd.<sup>2</sup> (34 g./m.<sup>2</sup>) for the heavier paper in (a) and the addition of a layer of the 1 oz./yd.<sup>2</sup> paper beneath the rayon web. Properties of the product are given in Table II. It should be noted that this particular technique gives a 12% loss of the starting fibers. The product has an abrasion resistance of 20 minutes.

EXAMPLE 15

A randomly oriented web of the rayon staple of Example 7 is hydraulically entangled at up to 700 psi. on a 20 x 20 mesh screen (19% open area) to give a nonwoven fabric of 1 oz./yd.<sup>2</sup> (34 g./m.<sup>2</sup>) weight.

(a) A sheet of soft wood pulp paper of Example 9 with a dry weight of 3 oz./yd.<sup>2</sup> (102 g./m.<sup>2</sup>) is placed on top of the above rayon nonwoven fabric and the composite passed at 3 ypm (2.7 mpm) under water streams from the orifices of Example 10 while resting on an 80 x 80 mesh screen (13% open area) as follows:

	<u>Passes</u>	<u>Pressure</u>		<u>Top Screen</u>
		<u>psi.</u>	<u>(kg./cm.<sup>2</sup>)</u>	
	2	300	(21)	yes
25	2	600	(42)	yes
	2	800	(56)	yes
	2	800	(56)	no

for a treatment of about 0.8 HP-hrs./lb. (1.1 Cal./g.) to give item (a).

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(b) The procedure is repeated to make item (b) with the substitution of a web containing 20% of 0.25-inch (6.3-mm.) rayon fibers and 80% wood pulp for the 100% wood pulp layer used for item (a).

5 Properties of the products are given in Table II.

(c) In a similar way, a product is prepared in which the paper layer is sandwiched between two outer layers of textile fibers. The product has high absorbency and a soft textile hand. It is suitable for use as a towel, or  
10 for absorbent pads.

TABLE II

Example	Fabric Weight oz/yd <sup>2</sup> (g./m <sup>2</sup> )	Strip Tensile MD x CD lb/in./oz/yd <sup>2</sup> (g/cm./g./m <sup>2</sup> )	Elongation MD x CD %	Modulus MD x CD lb/in./oz/yd <sup>2</sup> (g/cm./g./m <sup>2</sup> )	90/0 Ratio	Density g/cm <sup>3</sup>	Drape Flex cm	Opacity %	Abrasion Resistance minutes
7	2.4 (81)	2.3 x 2.9 (12 x 15)	44 x 53	12 x 7 (63 x 37)		0.14	3.7 x 3.0	69	0.5
8	2.3 (78)	3.2 x 2.3 (17 x 12)	37 x 62	13 x 4 (69 x 21)	0.52	0.13	3.5 x 3.0	67	1.5
9	3.6 (122)	4.2 x 3.1 (22 x 16)	45 x 48	5 x 4 (26 x 21)	0.62	0.14	3.0 x 2.6	71	3.0
10	2.8 (95)	1.0 (5)	67	2 (10)	0.71	0.09	3.7	96	7.8
11	3.7 (126)	5.2 x 5.2 (27 x 27)	128 x 142	12 x 11 (63 x 58)	0.44	0.13	3.8	77	270
12	1.4 (47)	2.6 x 2.0 (14 x 11)	37 x 47	10 x 7 (53 x 37)	0.70	0.08	2.6 x 2.7	44	
13	2.1 (71)	2.3 x 2.2 (12 x 12)	41 x 37	8 x 8 (42 x 42)	0.58	0.13	2.1 x 1.8	69	4.8
14a	2.5 (85)	3.4 x 2.9 (18 x 15)	45 x 53	8 x 4 (42 x 21)		0.17	2.5 x 2.5	79	30
14b	2.2 (75)	2.8 x 2.9 (15 x 15)	33 x 45	10 x 8 (53 x 42)					20
15a	3.8 (129)	1.4 x 1.7 (7.4 x 9)	39 x 54	2 x 3 (11 x 16)	0.72	0.15	2.1	81	10
15b	4.3 (146)	2.5 x 1.8 (13 x 10)	47 x 42	6 x 4 (31 x 21)	0.83	0.19	2.5	84	60

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EXAMPLE 16

The starting layer of textile fibers is a 1.6 oz/yd<sup>2</sup> (54 g/m<sup>2</sup>) weight web containing 88% of poly(ethylene terephthalate) continuous filaments of 3 dpf (with a potential spontaneous elongation of 12% upon heating at 200°C. or higher) and 12% of the copolymer poly(ethylene isophthalate/terephthalate) (80/20%) continuous filaments of 3 dpf. The random web is prepared by the process of British Patent No. 932,482 and the homopolymer fibers are processed according to U. S. Patent No. 2,952,879 to provide the potential elongation.

The above random web is placed on a 60 x 60 mesh screen (16% open area), covered with a sheet of kraft wood pulp weighing 1.5 oz/yd<sup>2</sup> (51 g/m<sup>2</sup>) and a 14 x 18 mesh (65% open area) screen placed on top. The entire assembly is passed under the water streams of Example 10. The top screen is removed and the treatment continued at 1000 and 1500 psi (70 and 105 kg/cm<sup>2</sup>) until a total energy of 1.0 HP-hrs/lb is applied to the sample. The fabric is a well entangled product of this invention.

The dry fabric is passed between moving screens through which air at 230°C. is passed to melt the copolymer fiber and further bond the structure. The surface of the fabric that faced the water streams is composed largely (≥75%) of paper fibers, the ends of which are bent down and embedded in the structure. The other side of the fabric has paper fiber ends protruding from the polyester web, which is somewhat rearranged and interpenetrated and entangled by the paper fibers.

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The bonded product has the following properties:

	Fabric weight	3.1 oz/yd <sup>2</sup> (105 g/m <sup>2</sup> )			
	Density	0.14 g/cm <sup>3</sup>			
	Strip tensile M.D.	5.7 lb/in//oz/yd <sup>2</sup> (30 g/cm//g/m <sup>2</sup> )			
5	C.D.	6.0	"	(32	" )
	Modulus, 5% M.D.	20	"	(105	" )
	C.D.	13	"	(68	" )
	Drape flex M.D. x C.D.	5.8 x 4.8 cm			
	Opacity	83%			
10	Abrasion resistance	56 minutes			
	90/0 ratio	0.46			

Since many different embodiments of the invention may be made without departing from the spirit and scope thereof, it is to be understood that the invention is not  
 15 limited by the specific illustrations except to the extent defined in the following claims.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. The improvement in the conventional paper-making process of preparing a stock suspension of fibers in water, continuously screening fibers from the stock to form a wet mat, mechanically removing water from the mat to form a sheet, wherein the improvement comprises thereafter supporting the sheet on an apertured backing member at a distance from orifices in a manifold which provides water, and jetting water on said sheet, said water supplied to said manifold at pressures of 200 to 2000 pounds per square inch to said orifices to form streams having an energy flux of at least 23,000 foot-poundsals/in.<sup>2</sup> second and a diameter of 2 to 10 mils at the treatment distance from said orifices, traversing the supported sheet with the streams until a stream energy of 0.05 to 2.0 horsepower-hours per pound of product has been applied, and drying the product.

2. The process defined in Claim 1 wherein the sheet is traversed with the streams while supported on a fine mesh screen to produce a felt-like product.

3. The process defined in Claim 1 wherein the sheet is traversed with a stream energy of 0.05 to 2.0 horsepower-hours per pound of product while supported on a fine mesh screen and is then treated with a stream energy of 0.05 to 1.0 horsepower-hour per pound while supported on a coarse apertured patterning member to form a patterned product.

4. The process defined in Claim 3 wherein the coarse apertured patterning member is a woven wire screen of about 10 to 30 mesh per inch and the appearance of the product resembles that of a woven textile fabric.

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5. The process defined in Claim 1 wherein said fibers consist essentially of 75% to 100% paper fibers and 0% to 25% textile staple fibers by weight.

6. The process defined in Claim 1 wherein said sheet is assembled on top of a layer of textile staple fibers, the assembly is supported on the apertured backing member and the supported assembly is traversed with the streams to form a laminated product.

7. The process of Claim 5 or Claim 6 characterized in that the sheet is dried before being traversed with the water streams.

1A



FIG. 1

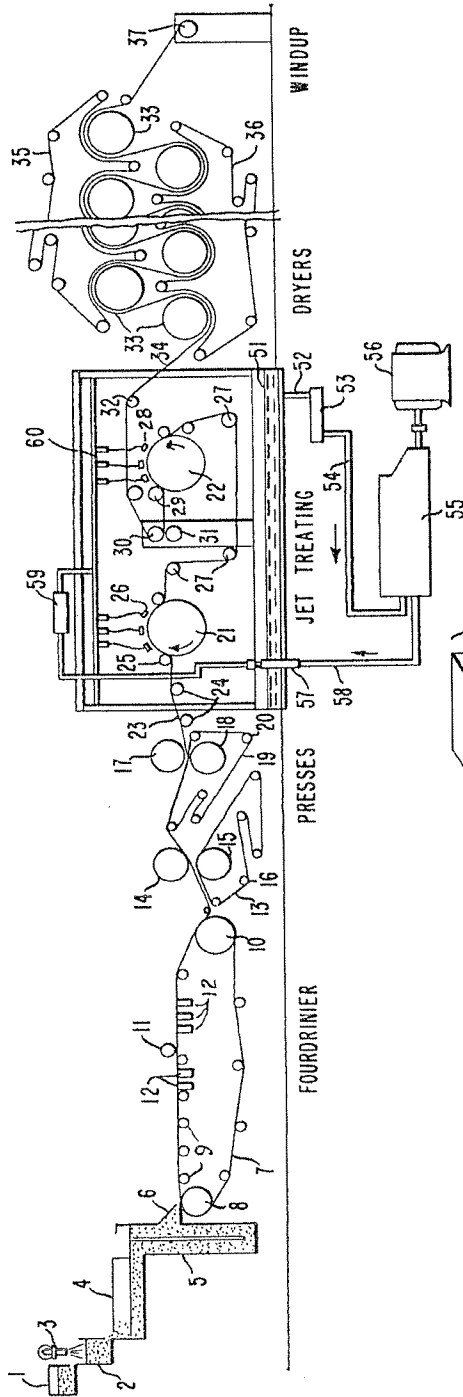
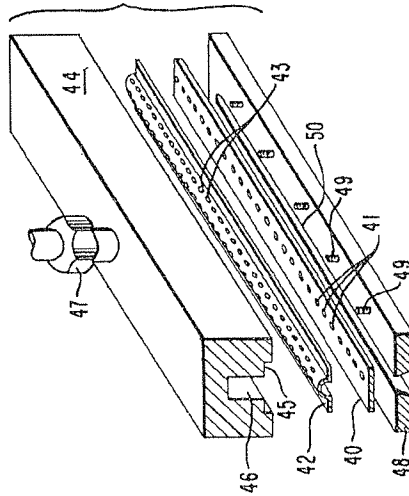


FIG. 2



INVENTOR

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PATENT AGENT

*James*



# United States Patent [19]

Sternlieb et al.

[11] Patent Number: 4,967,456

[45] Date of Patent: Nov. 6, 1990

## [54] APPARATUS AND METHOD FOR HYDROENHANCING FABRIC

[75] Inventors: Herschel Sternlieb, Brunswick, Me.; Jodie M. Siegel, Watertown; John M. Greenway, Westwood, both of Mass.

[73] Assignee: International Paper Company, Purchase, N.Y.

[21] Appl. No.: 382,160

[22] PCT Filed: Apr. 14, 1989

[86] PCT. No.: US85/01593

§ 371 Date: May 18, 1989

§ 102(e) Date: May 18, 1989

### Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 41,542, Apr. 23, 1987, abandoned, which is a continuation-in-part of Ser. No. 184,350, Apr. 21, 1988, abandoned.

[51] Int. Cl.<sup>5</sup> ..... D04H 1/46

[52] U.S. Cl. .... 28/104; 8/151.2; 28/167; 68/205 R; 428/225

[58] Field of Search ..... 28/104, 167; 8/151.2; 68/205 R; 428/225

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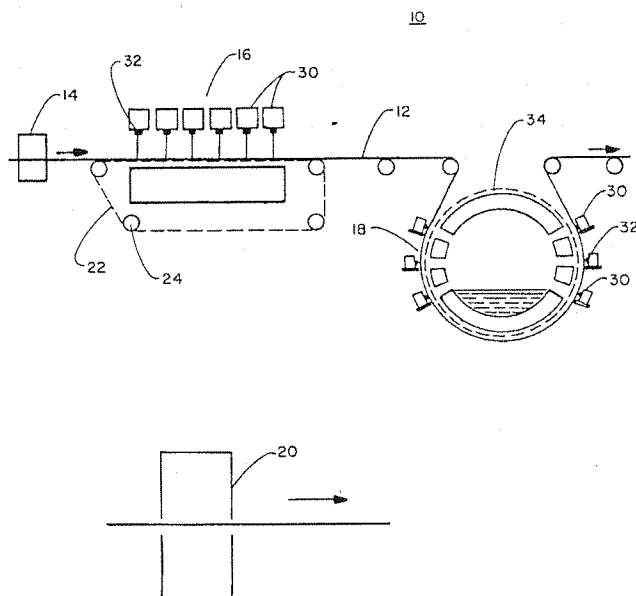
Primary Examiner—Philip R. Coe

Attorney, Agent, or Firm—Francis J. Clark

### [57] ABSTRACT

An apparatus 10 and related process for enhancement of woven and knit fabrics through use of dynamic fluids which entangle and bloom fabric yarns. A two stage enhancement process is employed in which top and bottom sides of the fabric are respectively supported on members 22, 34 and impacted with a fluid curtain including high pressure jet streams. Controlled process energies and use of support members 22, 34 having open areas 26, 36 which are aligned in offset relation to the process line produces fabrics having a uniform finish and improved characteristics including, edge fray, drape, stability, abrasion resistance, fabric weight and thickness.

41 Claims, 17 Drawing Sheets



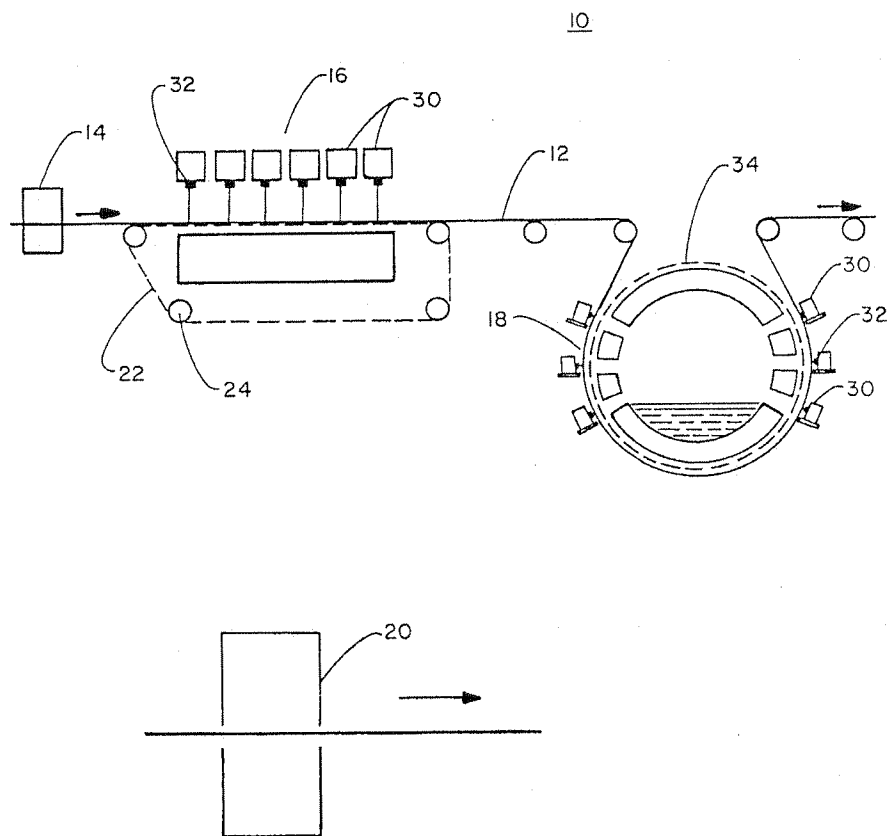


FIG. 1

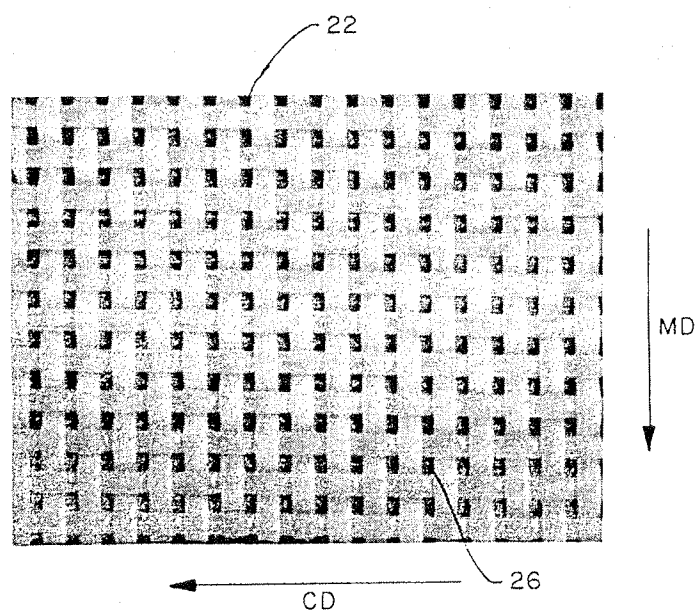


FIG. 2A

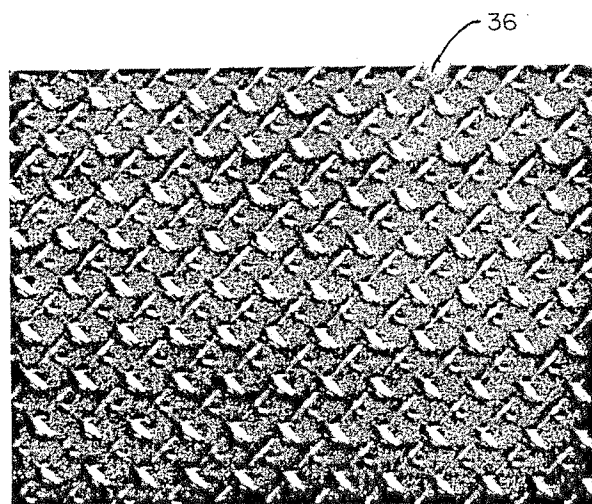


FIG. 2B

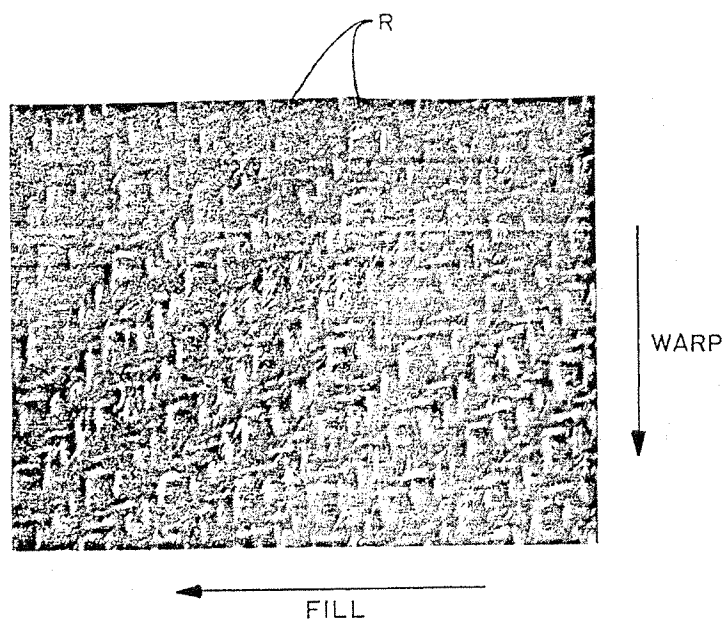


FIG. 3A

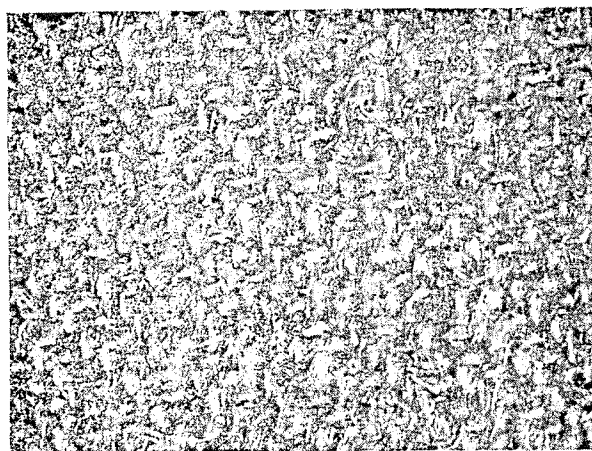


FIG. 3B

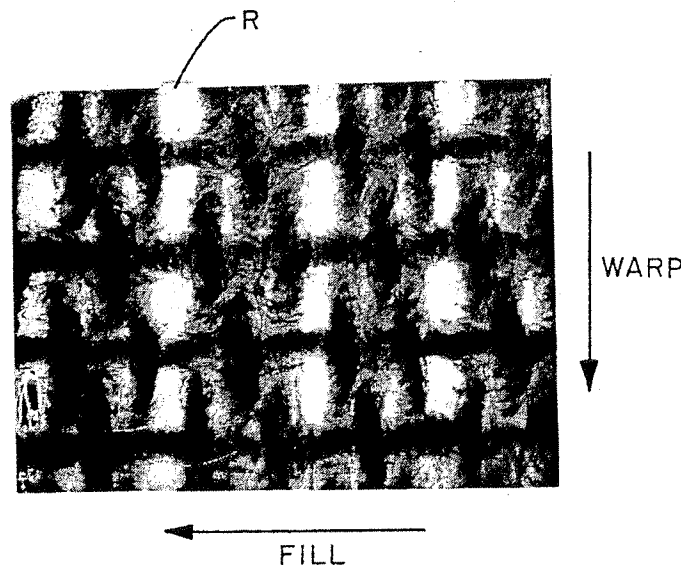


FIG. 4A

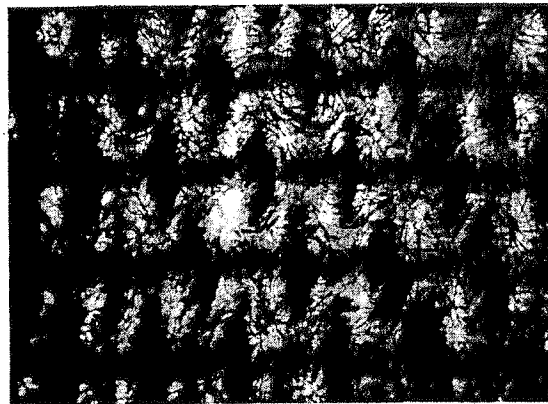
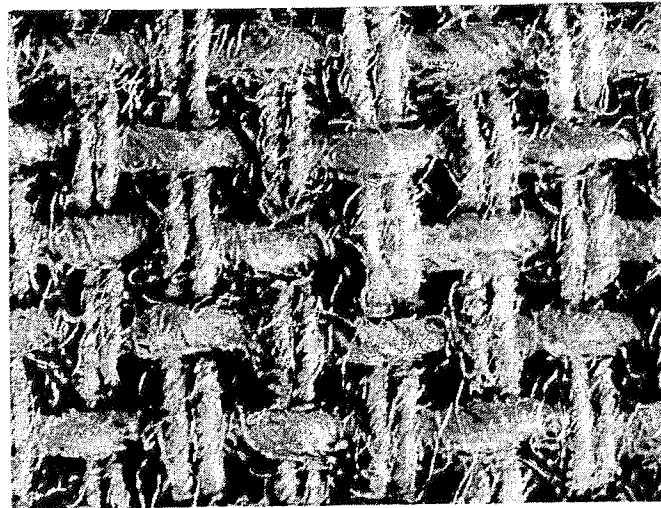


FIG. 4B



WARP

FILL

FIG. 5A

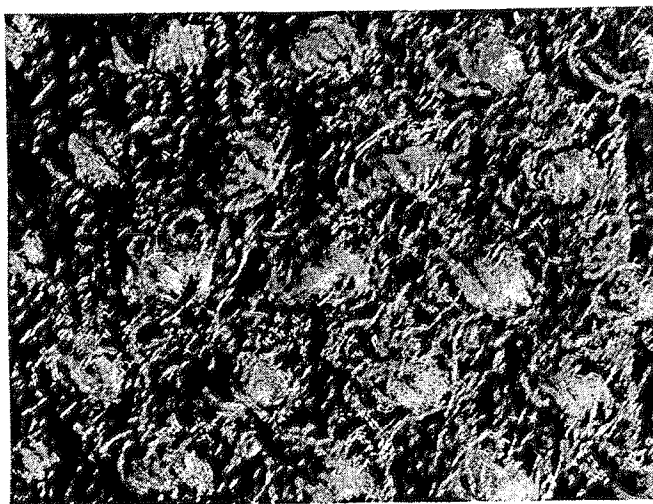
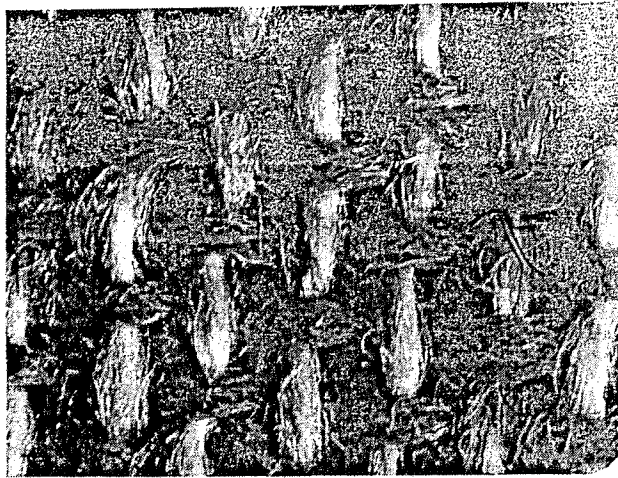


FIG. 5B



WARP

FILL

FIG. 6A

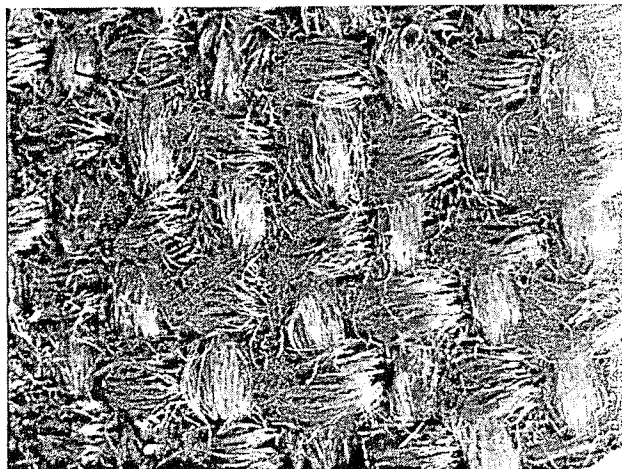
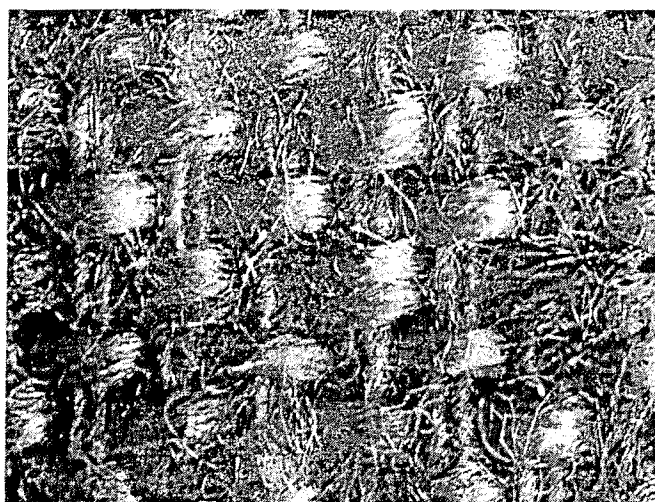


FIG. 6B



WARP

FILL

FIG. 7A

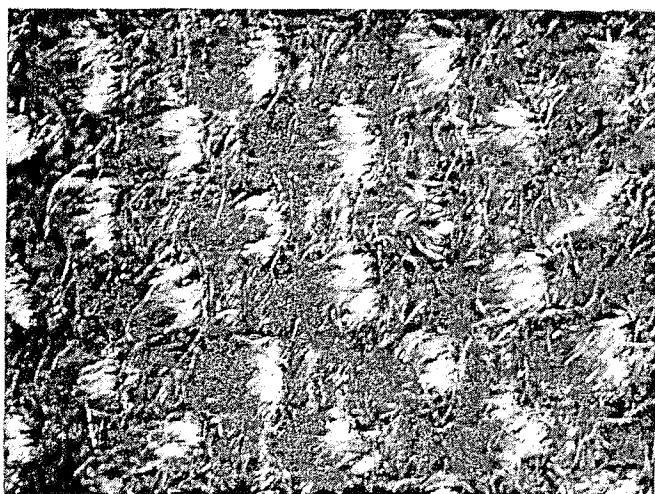
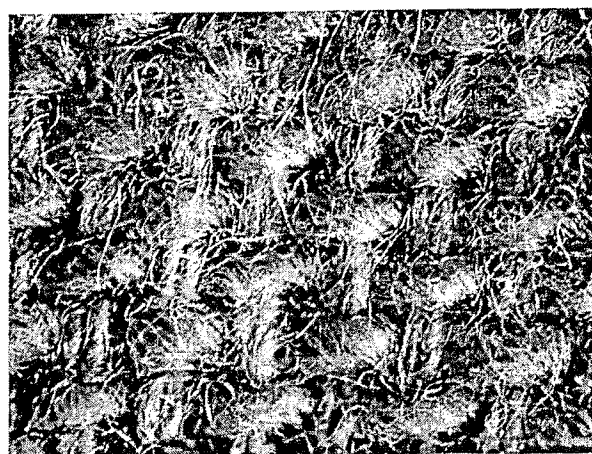


FIG. 7B



WARP  
↓

← FILL

FIG. 8A

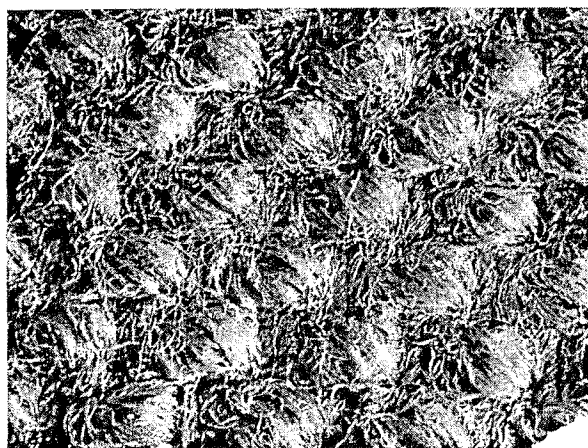


FIG. 8B

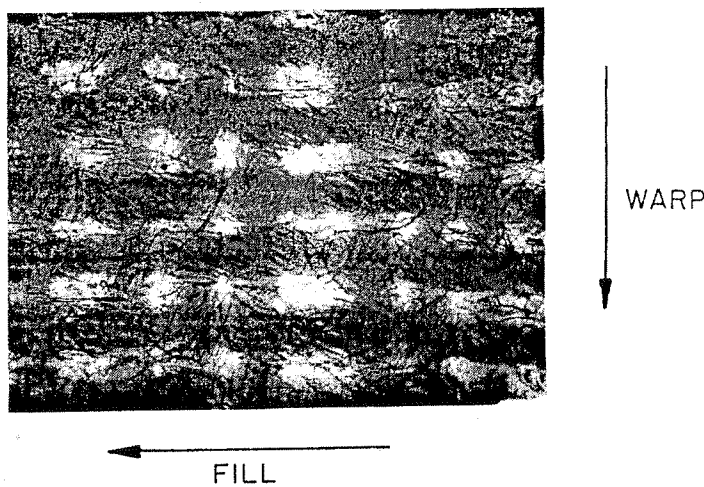


FIG. 9A

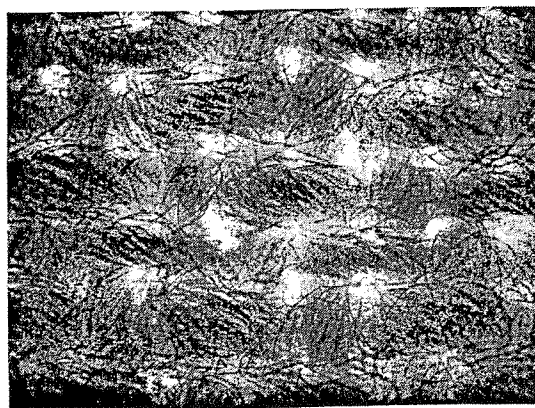
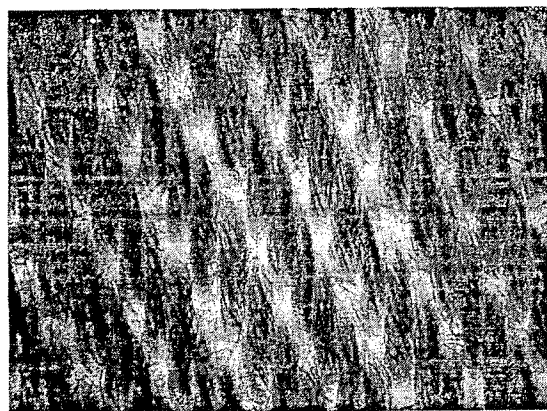


FIG. 9B



WARP

FILL

FIG. IOA

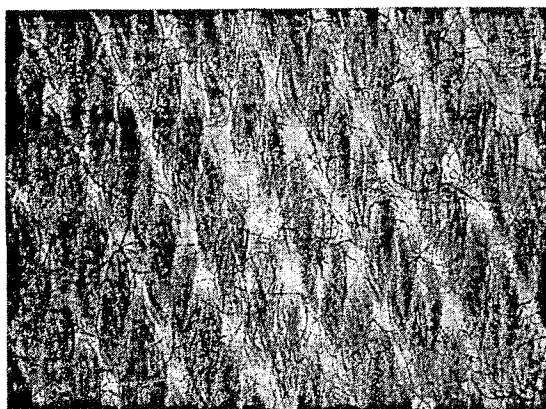


FIG. IOB

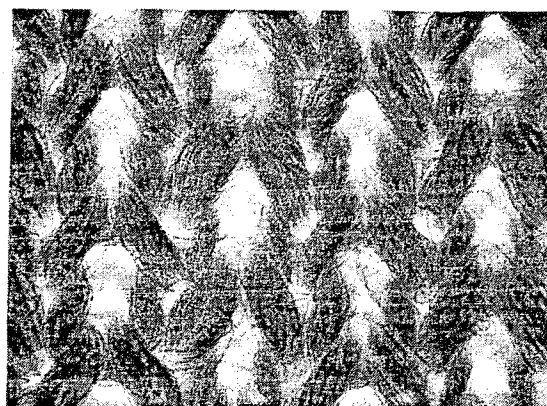
WALE  
↓←  
COURSE

FIG. IIA

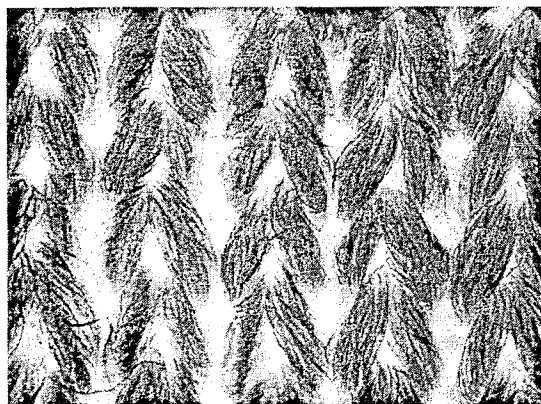


FIG. IIB

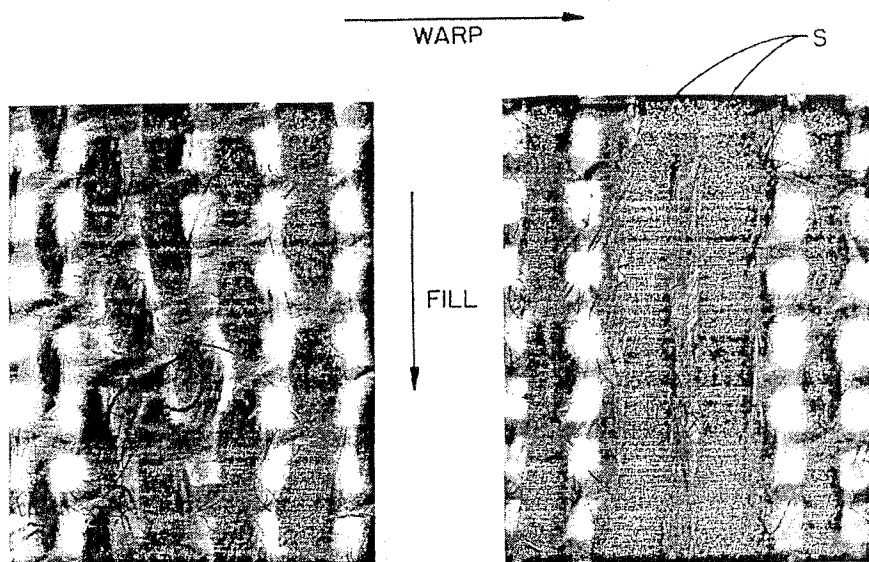


FIG. 12A

FIG. 12B



FIG. 13A

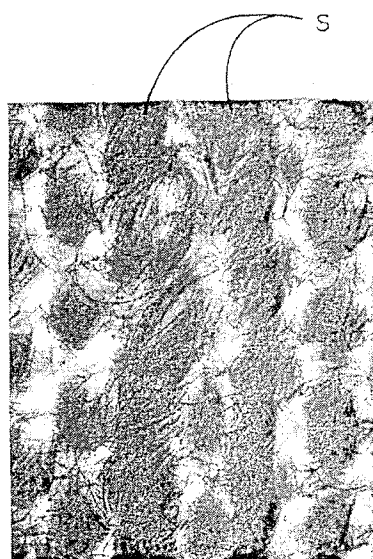


FIG. 13B

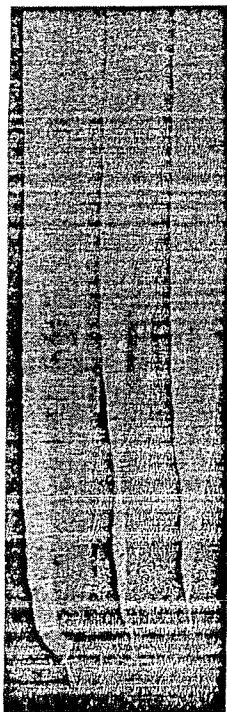


FIG. 14A

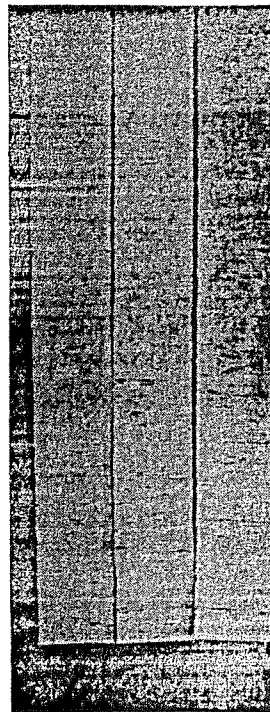


FIG. 14B

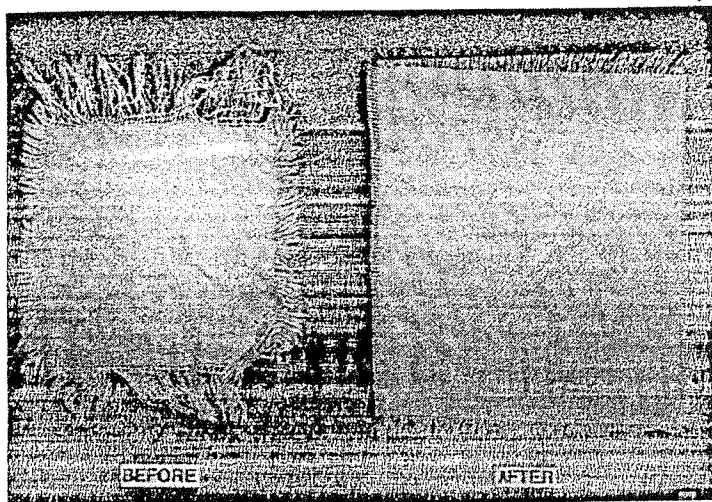


FIG. 15A

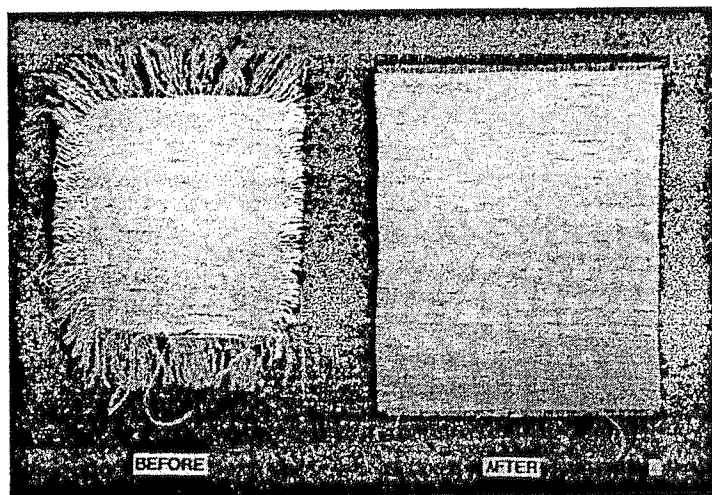


FIG. 15B

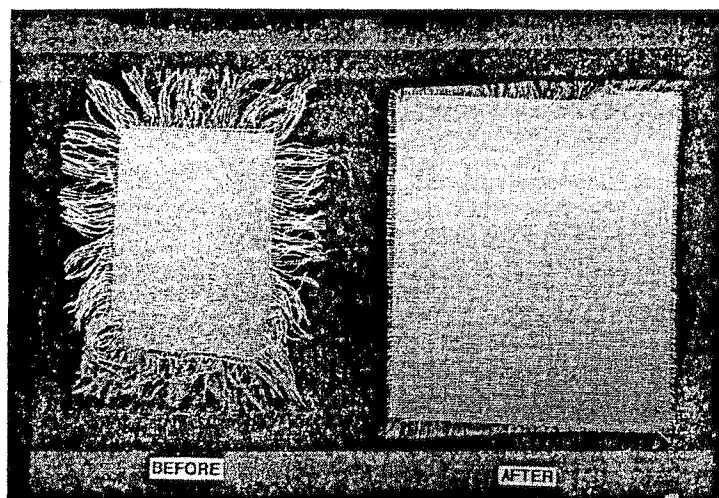


FIG. 15C

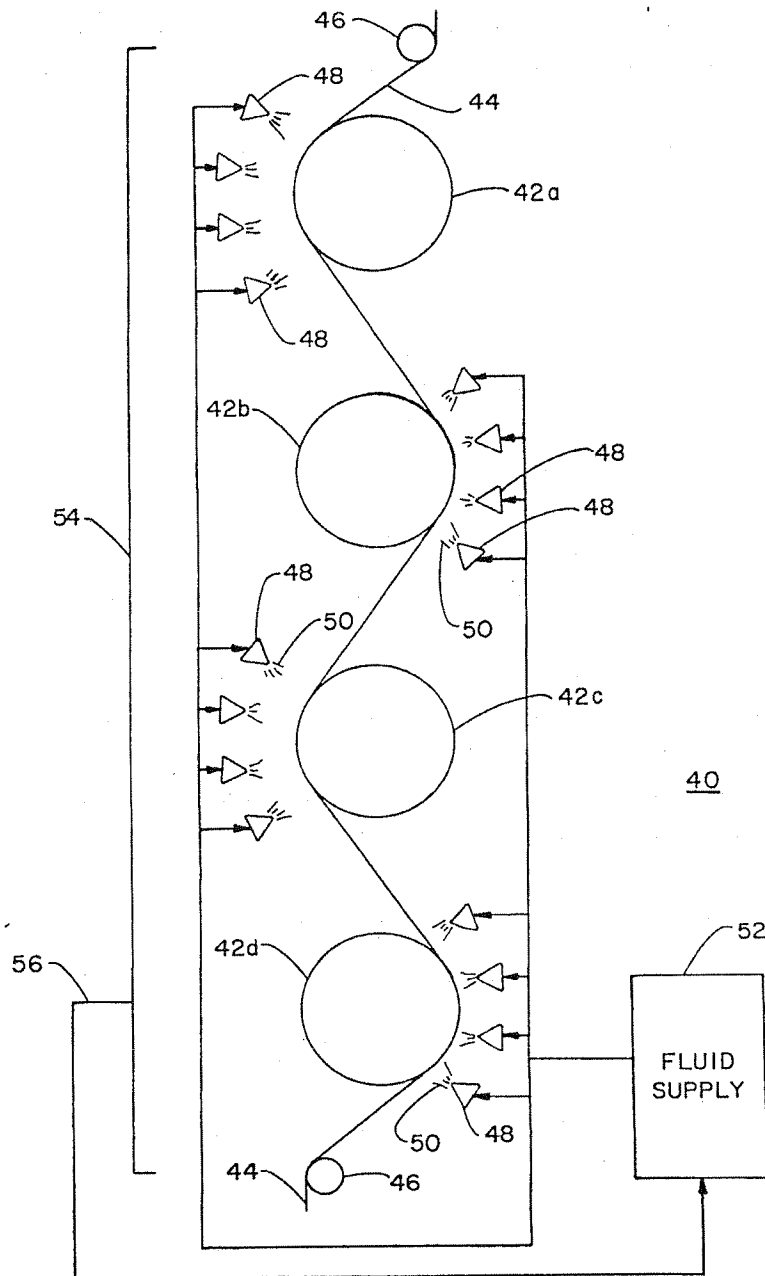


FIG. 16

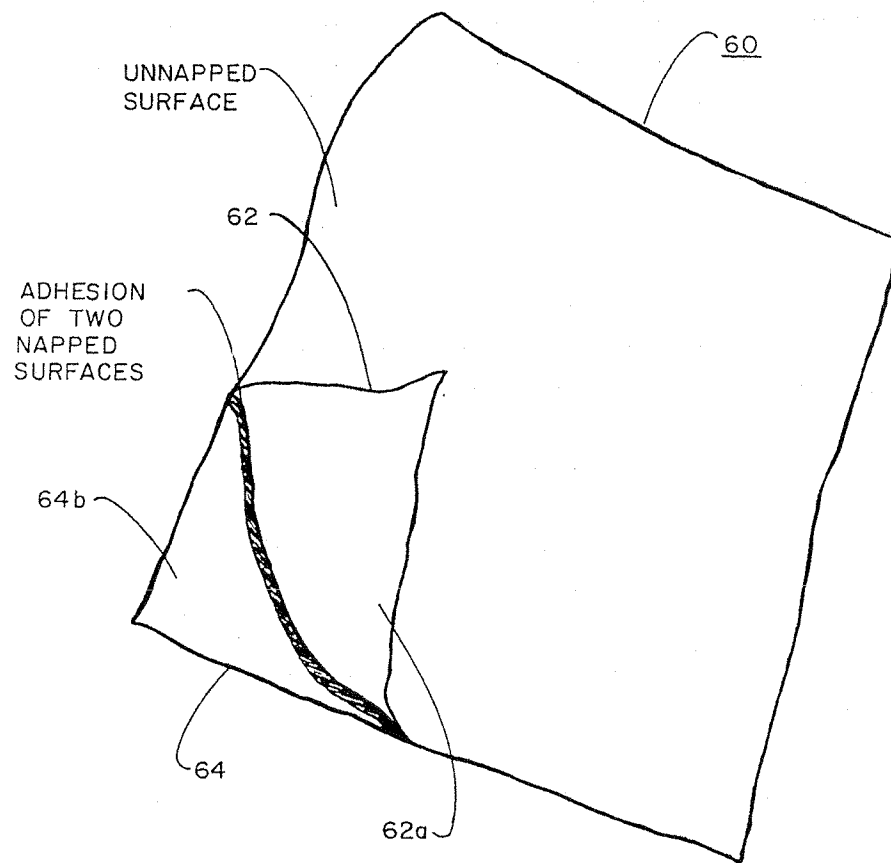


FIG. 17

## APPARATUS AND METHOD FOR HYDROENHANCING FABRIC

### CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. Ser. Nos. 07/041,542 and 07/184,350, respectively filed Apr. 23, 1987; and Apr. 21, 1988, and now both abandoned.

### FIELD OF INVENTION

This invention generally relates to a textile finishing process for upgrading the quality of woven and knit fabrics. More particularly, it is concerned with a hydro-entangling process which enhances woven and knit fabrics through use of dynamic fluid jets to entangle and cause fabric yarns to bloom. Fabrics produced by the method of the invention have enhanced surface finish and improved characteristics such as cover, abrasion resistance, drape, stability as well as reduced air permeability, wrinkle recovery, seam slippage, and edge fray.

### BACKGROUND ART

The quality of a woven or knit fabric can be measured by various properties, such as, the yarn count, thread count, abrasion resistance, cover, weight, yarn bulk, yarn bloom, torque resistance, wrinkle recovery, drape and hand.

Yarn count is the numerical designation given to indicate yarn size and is the relationship of length to weight.

Thread count in woven or knit fabrics, respectively, defines the number ends and picks, and wales and courses per inch of fabric. For example, the count of cloth is indicated by enumerating first the number of warp ends per inch, then the number of filling picks per inch. Thus, 68×72 defines a fabric having 68 warp ends and 72 filling picks per inch.

Abrasion resistance is the ability of a fabric to withstand loss of appearance, utility, pile or surface through destructive action of surface wear and rubbing.

Cover is the degree to which underlying structure in a fabric is concealed by surface material. A measure of cover is provided by fabric air permeability, that is, the ease with which air passes through the fabric. Permeability measures fundamental fabric qualities and characteristics such as filtration and cover.

Yarn bloom is a measure of the opening and spread of fibers in yarn.

Fabric weight is measured in weight per unit area, for example, the number of ounces per square yard.

Torque of fabric refers to that characteristic which tends to make it turn on itself as a result of twisting. It is desirable to remove or diminish torque in fabrics. For example, fabrics used in vertical blinds should have no torque, since such torque will make the fabric twist when hanging in a strip.

Wrinkle recovery is the property of a fabric which enables it to recover from folding deformations.

Hand refers to tactile fabric properties such as softness and drapability.

It is known in the prior art to employ hydroentangling processes in the production of nonwoven materials. In conventional hydroentangling processes, webs of nonwoven fibers are treated with high pressure fluids while supported on apertured patterning screens. Typically, the patterning screen is provided on a drum or continuous planar conveyor which traverses pressur-

ized fluid jets to entangle the web into cohesive ordered fiber groups and configurations corresponding to open areas in the screen. Entanglement is effected by action of the fluid jets which cause fibers in the web to migrate to open areas in the screen, entangle and intertwine.

Prior art hydroentangling processes for producing patterned nonwoven fabrics are represented by U.S. Pat. Nos. 3,485,706 and 3,498,874, respectively, to Evans and Evans et al., and U.S. Pat. Nos. 3,873,255 and 3,917,785 to Kalwaites.

Hydroentangling technology has also been employed by the art to enhance woven and knit fabrics. In such applications warp and pick fibers in fabrics are hydroentangled at crossover points to effect enhancement in fabric cover. However, conventional processes have not proved entirely satisfactory in yielding uniform fabric enhancement. The art has also failed to develop apparatus and process line technology which achieves production line efficiencies.

Australian Patent Specification 287821 to Bunting et al. is representative of the state of the art. Bunting impacts high speed columnar fluid streams on fabrics supported on coarse porous members. Preferred parameters employed in the Bunting process, described in the Specification Example Nos. XV-XVII, include 20 and 30 mesh support screens, fluid pressure of 1500 psi, and jet orifices having 0.007 inch diameters on 0.050 inch centers. Fabrics are processed employing multiple hydroentangling passes in which the fabric is reoriented on a bias direction with respect to the process direction in order to effect uniform entanglement. Data set forth in the Examples evidences a modest enhancement in fabric cover and stability.

Another approach of art is represented by European Patent Application No. 0 177 277 to Willbanks et al. which is directed to hydropatterning technology. Willbanks impinges high velocity fluids onto woven, knitted and bonded fabrics for decorative effects. Patterning is effected by redistributing yarn tension within the fabric - yarns are selectively compacted, loosened and opened - to impart relief structure to the fabric.

Fabric enhancement of limited extent is obtained in Willbanks as a secondary product of the patterning process. However, Gilpatrick fails to suggest or teach a hydroentangling process that can be employed to uniformly enhance fabric characteristics. See Willbanks Example 4, page 40.

There is a need in the art for an improved woven textile hydroenhancing process which is commercially viable. It will be appreciated that fabric enhancement offers aesthetic and functional advantages which have application in a wide diversity of fabrics. Hydroenhancement improves fabric cover through dynamic fluid entanglement and bulking of fabric yarns for improved fabric stability. These results are advantageously obtained without requirement of conventional fabric finishing processes.

The art also requires apparatus of uncomplex design for hydroenhancing textile materials. Commercial production requires apparatus for continuous fabric hydroenhancing and in-line drying of such fabrics under controlled conditions to yield fabrics of uniform specifications.

Accordingly, it is a broad object of the invention to provide an improved textile hydroenhancing process and related apparatus for production of a variety of

novel woven and knit fabrics having improved characteristics which advance the art.

A more specific object of the invention is to provide a hydroenhancing process for enhancement of fabrics made of spun and spun/filament yarn.

Another object of the invention is to provide a hydroenhancing process having application for the fabrication of novel composite and layered fabrics.

A further object of the invention is to provide a hydroenhancing production line apparatus which is less complex and improved over the prior art.

### DISCLOSURE OF THE INVENTION

In the present invention, these purposes, as well as others which will be apparent, are achieved generally by providing an apparatus and a related method for hydroenhancing woven and knit fabrics through dynamic fluid action. A hydroenhancing module is employed in the invention in which the fabric is supported on a member and impacted with a fluid curtain under controlled process energies. Enhancement of the fabric is effected by entanglement and intertwining of yarn fibers at cross-over points in the fabric weave or knit. Fabrics enhanced in accordance with the invention have a uniform finish and improved characteristics, such as, edge fray, drape, stability, wrinkle recovery, abrasion resistance, fabric weight and thickness.

According to the preferred method of the invention, the woven or knit fabric is advanced on a process line through a weft straightener to two in-line fluid modules for first and second stage fabric enhancement. Top and bottom sides of the fabric are respectively supported on members in the modules and impacted by fluid curtains to impart a uniform finish to the fabric. Preferred support members are fluid pervious, include open areas of approximately 25%, and have fine mesh patterns which permit fluid passage without imparting a patterned effect to the fabric. It is a feature of the invention to employ support members in the modules which include fine mesh patterned screens which are arranged in offset relation with respect to the process line. This offset orientation limits fluid streaks and eliminates reed marking in processed fabrics.

First and second stage enhancement is preferably effected by columnar fluid jets which impact the fabric at pressures within the range of 200 to 3000 psi and impart a total energy to the fabric of approximately 0.10 to 2.0 hp-hr/lb.

Following enhancement, the fabric is advanced to a tenter frame which dries the fabric to a specified width under tension to produce a uniform fabric finish.

Advantage in the invention apparatus is obtained by provision of a continuous process line of uncomplex design. The first and second enhancement stations include a plurality of cross-directionally ("CD") aligned and spaced manifolds. Columnar jet nozzles having orifice diameters of approximately 0.005 inches with center-to-center spacings of approximately 0.017 inches are mounted approximately 0.5 inches from the screens. At the process energies of the invention, this spacing arrangement provides a curtain of fluid which yields a uniform fabric enhancement. Use of fluid pervious support members which are oriented in offset relation, preferably 45°, effectively limits jet streaks and eliminates reed markings in processed fabrics.

Optimum fabric enhancement results are obtained in fabrics woven or knit of yarns including fibers with deniers and staple lengths in the range of 0.5 to 6.0, and

0.5 to 5 inches, respectively, and yarn counts in the range of 0.5s to 50s. Preferred yarn spinning systems of the invention fabrics include cotton spun, wrap spun, wool spun and friction spun.

Other objects, features and advantages of the present invention will be apparent when the detailed description of the preferred embodiments of the invention are considered in conjunction with the drawings which should be construed in an illustrative and not limiting sense as follows:

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view of a production line including a weft straightener, flat and drum hydroenhancing modules, and tenter frame, for the hydroenhancement of woven and knit fabrics in accordance with the invention;

FIGS. 2A and B are photographs at 10× magnification of 36×29 90° and 40×40 45° mesh plain weave support members, respectively, employed in the flat and drum enhancing modules of FIG. 1;

FIGS. 3A and B are photomicrographs at 10× magnification of a fine polyester woven fabric before and after hydroenhancement in accordance with the invention;

FIGS. 4A and B are photomicrographs at 16× magnification of the control and processed fabric of FIGS. 3A and B;

FIGS. 5A and B are photomicrographs at 10× magnification of a control and hydroenhanced woven acrylic fabric;

FIGS. 6A and B are photomicrographs at 10× magnification of a control and hydroenhanced acrylic fabric woven of wrap spun yarn;

FIGS. 7A and B are photomicrographs at 10× magnification of a control and hydroenhanced acrylic fabric woven of wrap spun yarn;

FIGS. 8A and B are photomicrographs at 10× magnification of a control and hydroenhanced acrylic fabric including open end wool spun yarn;

FIGS. 9A and B are photomicrographs at 16× magnification of a control and hydroenhanced wool nylon (80/20%) fabric;

FIGS. 10A and B are photomicrographs at 16× magnification of a control and hydroenhanced spun/filament polyester/cotton twill fabric;

FIGS. 11A and B are photomicrographs at 16× magnification of a control and hydroenhanced doubleknit fabric;

FIGS. 12A and B are front and back side photomicrographs at 16× magnification of a control wall covering fabric;

FIGS. 13A and B are front and back side photomicrographs at 16× magnification of the wall covering fabric of FIGS. 12A and B hydroenhanced in accordance with the invention;

FIG. 14 is a photomicrograph at 0.09× magnification of a control and hydroenhanced acrylic fabric strips, the fabric of FIGS. 7A and B, showing the reduction in fabric torque achieved in the invention process;

FIGS. 15 A-C are photomicrographs at 0.23× magnification, respectively, of the woven acrylic fabrics of FIGS. 5, 7 and 8, comprised of wrap spun and open end wool spun yarns, showing washability and wrinkle characteristics of control and processed fabrics;

FIG. 16 is a schematic view of an alternative production line apparatus for the hydroenhancement of woven and knit fabrics in accordance with the invention; and

FIG. 17 illustrates a composite fabric including napped fabric components which are bonded into an integral structure employing the hydroenhancing process of the invention.

#### BEST MODE OF CARRYING OUT THE INVENTION

With further reference to the drawings, FIG. 1 illustrates a preferred embodiment of a production line of the invention, generally designated 10, for hydroenhancement of a fabric 12 including spun and/or spun-filament yarns. The line includes a conventional weft straightener 14, flat and drum enhancing modules 16, 18, and a tenter frame 20.

Modules 16, 18 effect two sided enhancement of the fabric through fluid entanglement and bulking of fabric yarns. Such entanglement is imparted to the fabric in areas of yarn crossover or intersection. Control of process energies and provision of a uniform curtain of fluid produces fabrics having a uniform finish and improved characteristics including, edge fray, torque, wrinkle recovery, cupping, drape, stability, abrasion resistance, fabric weight and thickness.

#### METHOD AND MECHANISM OF THE ENHANCING MODULES

Fabric is advanced through the weft straightener 14 which aligns the fabric weft prior to processing in enhancement modules 16, 18. Following hydroenhancement, the fabric is advanced to the tenter frame 20, which is of conventional design, where it is dried under tension to produce a uniform fabric of specified width.

Module 16 includes a first support member 22 which is supported on an endless conveyor means including rollers 24 and drive means (not shown) for rotation of the rollers. Preferred line speeds for the conveyor are in the range of 10 to 500 ft/min. Line speeds are adjusted in accordance with process energy requirements which vary as a function of fabric type and weight.

Support member 22, which preferably has a flat configuration, includes closely spaced fluid pervious open areas 26. A preferred support member 22, shown in FIG. 2A, is a 36×29 90° mesh plain weave having a 23.7% open area, fabricated of polyester warp and shute round wire. Support member 22 is a tight seamless weave which is not subject to angular displacement or snag. Specifications for the screen, which is manufactured by Albany International, Appleton Wire Division, P.O. Box 1939, Appleton, Wis. 54913 are set forth in Table I.

TABLE I

Property	Support Screen Specifications	
	36 × 29 90° flat mesh	40 × 40 45° drum mesh
Wire	polyester	stainless steel
Warp wire	.0157	0.010
Shute wire	.0157	0.010
Weave type	plain	plain
Open area	23.7%	36%

Module 16 also includes an arrangement of parallel and spaced manifolds 30 oriented in a cross-direction ("CD") relative to movement of the fabric 12. The manifolds which are spaced approximately 8 inches apart each include a plurality of closely aligned and spaced columnar jet orifices 32 which are spaced approximately 0.5 inches from the support member 22.

The jet orifices have diameters and center-to-center spacings in the range of 0.005 to 0.010 inches and 0.017

to 0.034 inches, respectively, and are designed to impact the fabric with fluid pressures in the range of 200 to 3000 psi. Preferred orifices have diameters of approximately 0.005 inches with center-to-center spacings of approximately 0.017 inches.

This arrangement of fluid jets provides a curtain of fluid entangling streams which yield optimum enhancement in the fabric. Energy input to the fabric is cumulative along the line and preferably set at approximately the same level in modules 16, 18 (two stage system) to impart uniform enhancement to top and bottom surfaces of the fabric. Effective first stage enhancement of fabric yarn is achieved at an energy output of at least 0.05 hp-hr/lb and preferably in the range of 0.1 to 2.0 hp-hr/lb.

Following the first stage enhancement, the fabric is advanced to module 18 which enhances the other side of the fabric. Module 18 includes a second support member 34 of cylindrical configuration which is supported on a drum. The member 34 includes closely spaced fluid pervious open areas 36 which comprise approximately 36% of the screen area. A preferred support member 34, shown in FIG. 2B, is a 40×40 45° mesh stainless steel screen, manufactured by Appleton Wire, having the specifications set forth in Table I.

Module 18 functions in the same manner as the planar module 16. Manifolds 30 and jet orifices 32 are provided which have substantially the same specifications as in the first stage enhancement module. Fluid energy to the fabric of at least 0.5 hp-hr/lb and preferably in the range of 0.1 to 2.0 hp-hr/lb effects second stage enhancement.

Conventional weaving processes impart reed marks to fabrics. Illustrations of such markings are shown in FIGS. 3A and 4A which are photomicrographs at 10× and 16× magnification of a polyester LIBBEY brand fabric style no. S/x-A805 (see Table II). Reed marks in FIGS. 3A and 4A are designated by the letter "R".

The invention overcomes this defect in conventional weaving processes through use of a single and preferably two stage hydroenhancement process. Advantage is obtained in the invention process by orienting the drum support member 34 in offset relation, preferably 45°, relative to machine direction ("MD") of the hydroenhancing line. See FIGS. 2A and B.

Support members 22 and 34 are preferably provided with fine mesh open areas which are dimensioned to effect fluid passage through the members without imparting a patterned effect to the fabric. The preferred members have an effective open area for fluid passage in the range of 17-40%.

Comparison of the control and processed polyester fabric of FIGS. 3A, B and 4A, B illustrates the advantages obtained through use of the enhancement process. Reed marks R in control polyester fabric are essentially eliminated through enhancement of the fabric. The offset screen arrangement is also effective in diminishing linear jet streak markings associated with the enhancement process.

#### EXAMPLES I-XIII

FIGS. 3-15 illustrate representative woven and knit fabrics enhanced in accordance with the method of the invention, employing test conditions which simulate the line of FIG. 1. Table II sets forth specifications for the fabrics illustrated in the drawings.

As in the FIG. 1 line, the test manifolds 30 were spaced approximately 8 inches apart in modules 16, 18,

and provided with densely packed columnar jet orifices 32 of approximately 60/inch. Orifices 32 each had a diameter of 0.005 inches and were spaced approximately 0.5 inches from the first and second support members 22, 34.

The process line of FIG. 1 includes enhancement modules 16, 18 which, respectively, are provided with six manifolds. In the Examples, modules 16, 18 were each fitted with two manifolds 34. To simulate line conditions, the fabrics were advanced through multiple runs on the line. Three processing runs in each two manifold module was deemed to be equivalent to a six manifold module.

Fabrics were hydroenhanced at process pressures of approximately 1500 psi. Line speed and cumulative energy output to the modules were respectively maintained at approximately 30 fpm and 0.46 hp-hr/lb. Adjustments in the line speed and fluid pressure were made to accommodate differences in fabric weight for uniform processing and to maintain the preferred energy level.

Fabrics processed in the Examples exhibited marked enhancement in aesthetic appearance and quality including, characteristics such as cover, bloom, abrasion resistance, drape, stability, and reduction in seam slip-page, and edge fray.

Tables III-XI set forth data for fabrics enhanced in accordance with invention on the test process line. Standard testing procedures of The American Society for Testing and Materials (ASTM) were employed to test control and processed characteristics of fabrics. Data set forth in the Tables was generated in accordance with the following ASTM standards:

Fabric Characteristic	ASTM Standard
Weight	D3776-79
Thickness	D1777-64 (Ames Tester)
Tensile Load	D1682-64 (1975) (Cut strip/grab)
Elongation	D1682-64 (1975)
Air Permeability	D737-75 (1980) (Frazier)
Threa Count	D3775-79
Ball Burst	D3787-80A
Seam Slippage	D4159-82
Tongue Tear	D2261-71
Wrinkle Recovery	D1295-67 (1972)
Abrasion Resistance	D3884-80
Pilling	D3514-81

Washability tests were conducted in accordance with the following procedure. Weight measurements ("before wash") were taken of control and processed fabric samples each having a dimension of 8.5×11" (8.5" fill direction and 11" warp direction). The samples were then washed and dried in conventional washer and dryers three consecutive times and "after wash" measurements were taken. The percent weight loss of the pre and post wash samples was determined in accordance the following formula:

$$\% \text{ weight loss} = D/B \times 100$$

where, B=before wash sample weight; A=after wash sample weight; and D=B-A.

Photomicrographs of the fabrics, FIGS. 4-15, illustrate the enhancement in fabric cover obtained in the invention. Attention is directed to open areas in the unprocessed fabrics, photographs designated A, these areas are of reduced size in the processed fabrics in the photographs designated B. Hydroenhancement caused

fabric yarns to bloom and entangle at cross-over points, filling in open areas to improve cover and reduce air permeability in the fabrics.

FIGS. 12 and 13 are photomicrographs of a HYTEX brand wall covering fabric, manufactured by Hytex, Inc, Randolph, Mass. A multi-textured surface appearance of the fabric is provided by yarns which are woven through discrete areas of the front fabric surface. Free floating weave stitches, designated by the letter "S" in FIGS. 12B and 13B, are formed on the backside of the fabric.

Hydroenhancement of HYTEX wall covering fabric secured the free-floating stitches S to the fabric backside enhancing fabric stability and cover. See FIGS. 12B, 13B. In wall covering applications, fabric enhancement and associated stabilizing effects reduces or eliminates the need for adhesive backcoatings. Enhancement of the fabric also limits wicking of wall cover application adhesives through the fabric. Further advantage is obtained when enhanced fabrics are used in acoustic applications; elimination of backcoating reduces sound reflection and furthers efficient transmission of sound through the fabric.

TABLE II

Fabric Specifications	
Fiber Brand and Style Designation	Figure (s)
NOMEX S/x-A805*	3 A,B, 4 A,B
Fiber: 2 denier-1.9 inch	
Yarn: Open end cotton spun 17s	
LIBBEY S/022**	5 A,B
Warp:	
Fiber: 3 denier - 1.5 inch acrylic	
Yarn: Open end cotton spun 9s	
28 ends per inch	
Fill:	
Fiber: 3 denier - 3 inch acrylic	
Yarn: Open end wool spun 4s	
14, 16 or 18 picks per inch	
LIBBEY S/x-1160	6 A,B
Fiber: 3 denier-3 inch acrylic	
Yarn: Wrap spun w/100 den textured polyester 4s	
14 ends × 16 picks per inch	
LIBBEY S/406	7 A,B, 14 A,B
Warp:	
Fiber: 3 denier - 1.5 inch acrylic	
Yarn: Open end cotton spun 9s	
28 ends per inch	
Fill:	
Fiber: 3 denier - 3 inch acrylic	
Yarn: Hollow spun 6 twists/inch 4s	
14, 16 or 18 picks per inch	
LIBBEY S/152	8 A,B
Warp:	
Fiber: 3 denier - 2.5 inch acrylic	
Yarn: Open end cotton spun 4s	
14 ends per inch	
Fill:	
Fiber: 3 denier - 3 inch acrylic	
Yarn: Open end wool spun 2.6s	
14, 16 or 18 picks per inch	
Guilford Wool/Nylon	9 A,B
80% wool/20% nylon	
Polyester/cotton (53/47)	10 A,B
Weight: 10 ounces/yd <sup>2</sup>	
Yarn: Spun Filament	
Weave: 3 × 1 Twill	
Thread Count: 120 × 38	
50% Polyester/50% cotton Doubleknit	11 A,B
Yarn: wrap spun with 100 denier polyester wrap	

TABLE II-continued

Fabric Specifications	
Fiber Brand and Style Designation	Figure (s)
HYTEX Wall covering***	12, 13

\*LIBBEY is a trademark of W.S. Libbey Co., One Mill Street, Lewiston, ME 04240.  
 \*\*NOMEX is a trademark of E.I. Du Pont de Nemours and Company, Wilmington, Del.

\*\*\*HYTEX is a trademark of Hytex, Inc., Randolph, MA.

TABLE III

Nomex A805 - FIG. 4			
	Control	Processed	% Change
Weight (gsy)	195	197	+1.0
Thickness (mils)	42	42	0
Air Perm. (ft <sup>3</sup> /ft <sup>2</sup> /min)	331	156	-52.9
Strip Tensile (lbs/in)			
warp	115	132	+14.8
fill	59	47	-20.3
Elongation %			
warp	48	50	+4.2
fill	62	71	+14.5

TABLE IV

022/6075 (16 ppi) - FIG. 5			
	Control	Processed	% Change
Weight (gsy)	158	165	+4.4
Thickness (mils)	48	49	+2.1
Air Perm. (ft <sup>3</sup> /ft <sup>2</sup> /min)	406	259	-36.2
Strip Tensile (lbs/in)			
warp	34	36	+5.9
fill	37	31	-16.2
Elongation (%)			
warp	33	27	-18.2
fill	27	28	+3.7
Seam Slippage (lbs/in)			
warp	5	60	+1100.0
fill	7	55	+685.7
Tongue Tear (lbs)			
warp	18	10	-44.4
fill	21	8	-61.9
Wt. Loss In Wash (%)	37	5	-86.5
Wrinkle Recovery* (recovery angle)	123°	138°	+12.2

\*Under ASTM test standards (D1295-67) improvements in the wrinkle recovery of a fabric are indicated by an increase in the recovery angle.

TABLE V

LIBBEY S/x-1160 - FIG. 6			
	Control	Processed	% Change
Weight (gsy)	146.8	160.2	9.1
Thickness (mils)	38.1	52.7	38.3
Air Perm. (ft <sup>3</sup> /ft <sup>2</sup> /min)	457.2	188.5	-58.8
Grab Tensile (lbs/in)			
warp	80.2	89.3	11.4
fill	105.0	111.4	6.1
Elongation (%)			

TABLE V-continued

LIBBEY S/x-1160 - FIG. 6			
	Control	Processed	% Change
warp	30.0	34.0	13.3
fill	32.0	46.0	43.8
Ball Burst (lbs)	190	157	-17.4

TABLE VI

406/6075 (16 ppi) - FIG. 7			
	Control	Processed	% Change
Weight (gsy)	159	166	+4.4
Thickness (mils)	48	50	+4.2
Air Perm. (ft <sup>3</sup> /ft <sup>2</sup> /min)	351	184	-47.6
Strip Tensile (lbs/in)			
warp	42	36	-14.3
fill	66	58	-12.1
Elongation (%)			
warp	23	31	+34.8
fill	49	33	-32.7
Seam Slippage (lbs)			
warp	29	36	+89.5
fill	21	76	+261.9
Tongue Tear (lbs)			
warp	23	18	-21.7
fill	19	15	-1.1
Wt. Loss In Wash (%)	28	4	-85.7
Wrinkle Recovery (recovery angle)	140°	148°	+5.7

TABLE VII

152/6076 (16 ppi) - FIG. 8			
	Control	Processed	% Change
Weight (gsy)	231	257	+11.3
Thickness (mils)	259	238	-8.1
Air Perm. (ft <sup>3</sup> /ft <sup>2</sup> /min)	204	106	-48.0
Strip Tensile (lbs/in)			
warp	48	58	+20.8
fill	56	72	+28.6
Elongation (%)			
warp	33	33	0
fill	34	39	+14.7
Seam Slippage (lbs)			
warp	64	81	+26.6
fill	78	112	+43.6
Tongue Tear (lbs)			
warp	21	18	-14.3
fill	17	15	-11.8
Wt. Loss In Wash (%)	—	—	—
Wrinkle Recovery (recovery angle)	117°	136°	+16.2

TABLE VIII

Guilford Wool (80% wool/20% nylon) - FIG. 9			
	Control	Process	% Change
Air Perm.	243	147	-39.5

TABLE IXA

Spun/Filament - Bottom Weights - FIG. 10								
	Sample #1		Sample #2		Sample #3		Sample #4	
	Control	Proc	Control	Proc	Control	Proc	Control	Proc
Weight (gsy)	259.2	275.4	240.3	248.4	286.2	297.2	267.3	280.8
Thickness (mils)	39.7	39.2	35.0	35.3	44.2	41.5	40.0	38.0
Strip Tensiles (lbs./in.)								
Warp	206.98	208.87	195.50	200.86	183.09	189.95	206.43	207.87
Fill	85.55	56.23	84.21	71.83	80.88	83.01	80.16	82.14
Normalized Tensiles								

TABLE IXA-continued

	Spun/Filament - Bottom Weights - FIG. 10							
	Sample #1		Sample #2		Sample #3		Sample #4	
	Control	Proc	Control	Proc	Control	Proc	Control	Proc
(lbs./in.)								
Warp	7.98	7.58	8.05	8.09	6.40	6.39	7.65	7.40
Fill	3.30	2.04	3.54	2.89	2.83	2.79	3.03	2.93
Elongation (%)								
Warp	42.0	55.3	36.5	39.1	40.9	43.5	46.1	51.2
Fill	23.6	25.6	24.0	20.0	23.5	20.3	22.9	22.4
Air Perm.	50.9	27.3	43.5	28.8	45.8	21.8	51.4	25.4
(ft. <sup>3</sup> /ft. <sup>2</sup> /min)								
Thread Count (wxf)	120 × 40	120 × 41	120 × 45	120 × 45	120 × 38	120 × 42	120 × 42	120 × 43
Mullen Burst (lbs.)	161.2	222.2	187.2	228.8	161.0	217.8	205.0	242.2
Normalized Burst	62.2	80.7	77.9	92.1	56.2	73.3	76.7	86.3
(lbs./g × 10 <sup>2</sup> )								

TABLE IXB

Sample	Abrasion - Spun Filament-Bottom Weights - FIG. 10 ASTM Standard - Twill side up; 500 cycles; 500 g weight; H-18 wheels				
	Weight Before (g)	Weight After (g)	Weight Loss (g)	% Loss	% Improvement
1C	3.32	3.02	0.30	9.0	23%
1P	3.36	3.13	0.23	6.9	
2C	4.64	4.16	0.48	10.4	48%
2P	4.83	4.57	0.26	5.4	
3C	4.73	4.47	0.26	5.5	18%
3P	4.91	5.13	0.22	4.5	
4C	4.47	4.18	0.29	6.5	41%
4P	4.71	4.53	0.18	3.8	

TABLE X

	Doubleknit - FIG. 11		
	Control	Processed	% Change
Air Perm. (Ft <sup>3</sup> /ft <sup>2</sup> min)	113.1	95.1	-15.9
Abrasion	1.0	0.6	-40.0
ASTM (D-3884-80): 250 Cycles, H-18 wheel			
Pilling (1-5 rating)	4.3	4.3	0
ASTM (D-3914-81): 300 cycles			

FIGS. 14A, B are photomicrographs of control and processed acrylic vertical blind fabric, manufactured by W. S. Libbey, style designation S/406. Enhancement of the fabric reduces fabric torque which is particularly advantageous in vertical blind applications. The torque reduction test of FIGS. 14A, B employed fabric strips 84" long and 3.5" wide, which were suspended vertically without restraint. Torque was measured with reference to the angle of fabric twist from a flat support surface. As can be seen in the photographs, a torque of 90° in the unprocessed fabric, FIG. 14A, was eliminated in the enhancement process.

FIGS. 15A-C are macrophotographs of control and processed acrylic fabrics, LIBBEY style nos. 022, 406 and 152, respectively, which were tested for washability. Unprocessed fabrics exhibited excessive fraying and destruction, in contrast to the enhanced fabrics which exhibit limited fraying and yarn (weight) loss. Table XI sets forth washability test weight loss data.

TABLE XI

Sample	022, 406, 152 - FIGS. 15 A-C Percent Weight Loss (3 wash/dry cycles)	
	Control	Processed
022	36.5	5.0
406	28.0	4.0

TABLE XI-continued

Sample	022, 406, 152 - FIGS. 15 A-C Percent Weight Loss (3 wash/dry cycles)	
	Control	Processed
152	28.1	7.2

FIG. 16 illustrates an alternative embodiment of the invention apparatus, generally designated 40. The apparatus includes a plurality of drums 42a-d over which a fabric 44 is advanced for enhancement processing. Specifically, the fabric 44 traverses the line in a sinuous path under and over the drums 42 in succession. Rollers 46a and b are provided at opposite ends of the line adjacent drums 42a and d to support the fabric. Any or all of the drums can be rotated by a suitable motor drive (not shown) to advance the fabric on the line.

A plurality of manifolds 48 are provided in groups, FIG. 16 illustrates groups of four, which are respectively spaced from each of the drums 42a-d. An arrangement of manifold groups at 90° intervals on the sinuous fabric path successively positions the manifolds in spaced relation with respect to opposing surfaces of the fabric. Each manifold 48 impinges columnar fluid jets 50, such as water, against the fabric. Fluid supply 52 supplies fluid to the manifolds 48 which is collected in liquid sump 54 during processing for recirculation via line 56 to the manifolds.

The support drums 42 may be porous or non-porous. It will be recognized that advantage is obtained through use of drums which include perforated support surfaces. Open areas in the support surfaces facilitate recirculation of the fluid employed in the enhancement process.

Further advantage is obtained, as previously set forth in discussion of the first embodiment, through use of support surfaces having a fine mesh open area pattern which facilitates fluid passage. Offset arrangement of the support member orientations, for example at 45° offset orientation as shown in FIG. 2, limits process water streak and weave reed marks in the enhanced fabric.

Enhancement is a function of energy which is imparted to the fabric. Preferred energy levels for enhancement in accordance with the invention are in the range of 0.1 to 2.0 hp-hr/lb. Variables which determine process energy levels include line speed, the amount and velocity of liquid which impinges on the fabric, and fabric weight and characteristics.

Fluid velocity and pressure are determined in part by the characteristics of the fluid orifices, for example,

columnar versus fan jet configuration, and arrangement and spacing from the process line. It is a feature of the invention to impinge a curtain of fluid on a process line to impart an energy flux of approximately 0.46 hp-hr/lb to the fabric. Preferred specifications for orifice type and arrangement are set forth in description of the embodiment of FIG. 1. Briefly, orifices 16 are closely spaced with center-to-center spacings of approximately 0.017 inches and are spaced 0.5 inches from the support members. Orifice diameters of 0.005 inches and densities of 60 per manifold inch eject columnar fluid jets which form a uniform fluid curtain.

The following Examples are representative of the results obtained on the process line illustrated in FIG. 17.

#### EXAMPLE XIV

A plain woven 100% polyester fabric comprised of friction spun yarns having the following specifications was processed in accordance with the invention: count of 16×10 yarns/in.<sup>2</sup>, weight of 8 ounces/yd.<sup>2</sup>, an abrasion resistance of 500 grams (measured by 50 cycles of a CS17 abrasion test wheel) and an air permeability of 465 ft<sup>3</sup>/ft<sup>2</sup>/min.

The fabric was processed on a test line to simulate a speed of 300 ft/min. on process apparatus including four drums 42 and eighteen nozzles 16 at a pressure of approximately 1500 psi. Energy output to fabric at these process parameters was approximately 0.46 hp-hr/lb. Table XII sets forth control and processed characteristics of the fabric.

TABLE XII

100% Polyester Friction Spun Fabric		
Fabric Characteristic	Control	Processed
Count (yarns/in. <sup>2</sup> )	16 × 10	17 × 10
Weight (ounces/yd. <sup>2</sup> )	8	8.2
Abrasion resistance (cycles)	50	85
Air permeability (ft <sup>3</sup> /ft <sup>2</sup> /min.)	465	181

#### EXAMPLES XV AND XVI

The process conditions of Example XIV were employed to process a plain woven cotton osnaburg and plain woven polyester ring spun fabrics yielding the results set forth in Tables XIV and XV.

TABLE XV

Plain Woven Cotton Osnaburg		
Fabric Characteristic	Control	Processed
Count (yarns/in. <sup>2</sup> )	32 × 26	32 × 32
Abrasion resistance (cycles)	140	344
Air permeability (ft <sup>3</sup> /ft <sup>2</sup> /min.)	710	120

TABLE XIV

Fabric Characteristic	Control	Processed
Count (yarns/in. <sup>2</sup> )	44 × 28	48 × 32
Abrasion resistance (cycles)	100	225
Air permeability (ft <sup>3</sup> /ft <sup>2</sup> /min.)	252	63

Fabrics processed in Examples XIV-XVI are characterized by a substantial reduction in air permeability and increase in abrasion resistance. Process energy levels in these Examples were approximately 0.46 hp-hr/lb. It has been discovered that there is a correlation between process energy and enhancement. Increased energy levels yield optimum enhancement effects.

The foregoing Examples illustrate applications of the hydroenhancing process of the invention for upgrading the quality of single ply woven and knit fabrics.

In an alternative application of the hydroenhancing process of the invention, fabric strata are hydrobonded into integral composite fabric. FIG. 17 illustrates a composite flannel fabric 60 including fabric layers 62, 64. Hydrobonding of the layers is effected by first napping opposing surfaces 62a, 64a of each of the layers to raise surface fibers. The opposing surfaces 62a, 64a are then arranged in overlying relation and processed on the production line of the invention. See FIGS. 1 and 16. Enhancement of the layers 62, 64 effects entanglement of fibers in the napped surfaces and bonding of the layers to form an integral composite fabric 60. Exterior surfaces 62b, 64b are also enhanced in the process yielding improvements in cover and quality in the composite fabric.

Napped surfaces 62a, 62b are provided by use of conventional mechanical napping apparatus. Such apparatus include cylinders covered with metal points or teasel burrs which abrade fabric surfaces.

Advantageously, composite fabric 60 is manufactured without requirement of conventional laminating adhesives. As a result, the composite fabric breaths and has improved tactile characteristics than obtained in prior art laminated composites. It will be recognized that such composite fabrics have diverse applications in fields such as apparel and footwear.

Optimum enhancement (in single and multi-ply fabrics) is a function of energy. Preferred results are obtained at energy levels of approximately 0.46 hp-hr/lb. Energy requirements will of course vary for different fabrics as will process conditions required to achieve optimum energy levels. In general, process speeds, nozzle configuration and spacing may be varied to obtain preferred process energy levels.

Enhanced fabrics of the invention are preferably fabricated of yarns including fibers having deniers and lengths, respectively, in the ranges of 0.3 to 10.0 and 0.5 to 6.0 inches, and yarn counts of 0.5s to 80s. Optimum enhancement is obtained in fabrics having fiber deniers in the range of 0.5 to 6, staple fibers of 0.5 to 6.0 inches, and yarn counts in the range of 0.5s to 50s. Preferred yarn spinning systems employed in the invention fabrics include cotton spun, wrap spun and wool spun. Experimentation indicates that preferred enhancement results are obtained in fabrics including low denier, short lengths fibers, and loosely twisted yarns.

The invention advances the art by recognizing that superior fabric enhancement can be obtained under controlled process conditions and energy levels. Heretofore, the art has not recognized the advantages and the extent to which hydroenhancement can be employed to upgrade fabric quality. It is submitted that the results achieved in the invention reflect a substantial and surprising contribution to the art.

Numerous modifications are possible in light of the above disclosure. For example, although the preferred process and apparatus employ fluid pervious support members, non-porous support members are within the scope of the invention. Similarly, FIGS. 1 and 16 respectively illustrate two and four stage enhancement process lines. System configurations which include one or more modules having flat, drum or other support member configuration may be employed in the invention.

It will be recognized that the process of the invention has wide application for the production of a diversity of enhanced fabrics. Thus, the Examples are not intended to limit the invention.

Finally, although the disclosed enhancement process employs columnar jet orifices to provide a fluid curtain, other apparatus may be employed for this purpose. Attention is directed to the International Patent Application (RO/US) to Siegel et al., entitled "Apparatus and Method For Hydropatterning Fabric", filed concurrently herewith, assigned to Veratec, Inc., which discloses a divergent jet fluid entangling apparatus for use in hydropatterning woven and nonwoven textile fabrics.

Therefore, although the invention has been described with reference to certain preferred embodiments, it will be appreciated that other hydroentangling apparatus and processes may be devised, which are nevertheless within the scope and spirit of the invention as defined in the claims appended hereto.

We claim:

1. A method for enhancing and finishing textile fabrics including spun and/or spun filament yarns which intersect at cross-over points, and first and second sides, the fabric including yarn fibers having deniers and lengths in the range of 0.3 to 16.0 and 0.5 to 8 inches, respectively, and yarn counts in the range of 0.5s to 80s, the method comprising the steps of:

supporting the fabric on a first support member, and traversing the first side of said fabric with a first continuous curtain of fluid for sufficient duration to effect entanglement of said yarns at the cross-over points, thereby enhancing fabric cover and quality, said curtain of fluid impacting the fabric with an energy in the range 0.1 and 2.0 hp-hr/lb.

2. The method of claim 1, wherein said fluid curtain is provided by columnar fluid jet orifices having a diameter of approximately 0.005 inches, center-to-center spacing of approximately 0.017 inches, and spacing from said first support member of approximately 0.5 inches, said fluid jets impinging the fabric with fluids at pressure of approximately 1500 psi.

3. The method of claim 2, wherein said support member includes a pattern of closely spaced fluid pervious open areas aligned in a first direction to effect fluid passage through said support member.

4. The method of claim 3, wherein said open areas occupy approximately 17 to 40% of said support member.

5. The method of claim 1, comprising the further steps of:

supporting said enhanced fabric on a second support member, and

traversing the second side of said enhanced fabric in a second enhancement stage with a second continuous fluid curtain for sufficient duration to further enhance fabric cover and provide a uniform fabric finish,

said second enhancement stage impacting the fabric with an energy in the range 0.1 and 2.0 hp-hr/lb.

6. The method of claim 5, wherein:

said first and second fluid curtains are provided by columnar fluid jets each having a diameter of approximately 0.005 inches and center-to-center spacing of approximately 0.017 inches, said fluid curtains are spaced approximately 0.5 inches from said first and second members, and said fluid jets

impinge the fabric with fluids at a pressure of approximately 1500 psi,

said first and second support members each include a pattern of closely spaced fluid pervious open areas, respectively aligned in first and second directions, said open areas being dimensioned to effect fluid passage through said support members without imparting a patterned effect to the fabric.

7. The method of claim 6, wherein said open areas occupy approximately 17 to 40% of each of said first and second support members.

8. The method of claim 7, wherein said first and second support members respectively have flat and drum configurations.

9. The method of claim 8, wherein said first and second directions are offset approximately 45°.

10. The method of claim 7, wherein said first and second support members have drum configurations.

11. The method of claim 10, wherein said first and second directions are offset approximately 45°.

12. The method of claim 6, comprising the further step, following said second stage enhancement, of drying the enhanced fabric to a specified width under tension.

13. An enhanced textile fabric made by the method of claim 6, the fabric including yarn fibers having deniers and lengths in the range of 0.3 to 16 and 0.5 to 8 inches, respectively, and thread counts in the range of 0.5s to 80s, the yarn cross-over points in the fabric weave define interstitial open areas, wherein the process effects enhancement of the yarns in the interstitial open areas, thereby enhancing fabric cover.

14. An enhanced textile fabric made by the method of claim 6, the fabric including yarn fibers having deniers and lengths in the range of 0.5 to 6 and 0.5 to 8 inches, respectively, and thread counts in the range of 0.5s to 50s, the yarn cross-over points in the fabric weave define interstitial open areas, wherein the process effects enhancement of the yarns in the interstitial open areas, thereby enhancing fabric cover, and yields a reduction in fabric air permeability in the range of 10 to 90%.

15. An enhanced woven polyester fabric made by the method of claim 6, wherein the fabric includes 2 denier, 1.9 inch polyester fiber, open-end cotton spun warp having a yarn number of 17s and count of 49×23 per inch, and the process yields an approximate 48% reduction in air permeability in the fabric.

16. An enhanced woven acrylic fabric made by the method of claim 6, wherein the fabric includes 3 denier, 1.5 inch fiber, open-end cotton warp yarn having a yarn number of 9s, 28 ends per inch, and a 3 denier, 3 inch acrylic fiber, open-end wool spun fill yarn having a number of 4s, 16 picks per inch, and the process yields an approximate 36% reduction in air permeability in the fabric.

17. An enhanced acrylic wrap spun fabric made by the method of claim 6, wherein the fabric includes 3 denier, 3.0 inch acrylic fiber, wrap spun with 100 denier textured polyester yarn having a yarn number of 4s and count of 14×16 per inch, and the process yields an approximate 65% reduction in air permeability in the fabric.

18. An enhanced woven acrylic fabric made by the method of claim 6, wherein the fabric includes 3 denier, 1.5 inch acrylic fiber, open-end cotton spun warp yarn having a yarn number of 9s, 28 ends per inch, and a 3 denier, 3 inch acrylic fiber, hollow wrap spun fill yarn, 6 twists per inch having a number of 4s, 16 picks per

inch, and the process yields an approximate 48% reduction in air permeability in the fabric.

19. An enhanced woven acrylic fabric made by the method of claim 6, wherein the fabric includes 3 denier, 1.5 inch acrylic fiber, open-end wool spun warp yarn having a yarn number of 4s, 14 ends per inch, and a 3 denier, 3 inch acrylic fiber, open-end wool spun fill yarn having a yarn number of 2.6s, 16 picks per inch, and the process yields an approximate 48% reduction in air permeability in the fabric.

20. An enhanced woven fabric made by the method of claim 6, wherein the fabric includes 80% wool/20% nylon in a 2×1 twill weave, and the process yields an approximate 49.5% reduction in air permeability in the fabric.

21. An enhanced 53% polyester/47% cotton fabric made by the method of claim 6, wherein the fabric includes a 3×1 twill weave, a thread count of 120 ends×38 picks, and the process yields an approximate 50.6% reduction in air permeability in the fabric.

22. An enhanced 50% polyester/50% cotton doubleknit fabric made by the method of claim 6, wherein the fabric includes wrap spun yarn with 100 denier polyester wrap, and the process yields an approximate 16% reduction in air permeability in the fabric.

23. An enhanced woven or knit textile fabric which comprises: spun and/or spun filament yarns which intersect at cross-over points to define interstitial open areas, said yarns including fibers having deniers and lengths in the range of 0.3 to 16.0 and 0.5 to 8 inches, respectively, wherein said yarns are fluid entangled in said interstitial open areas by application of fluid energy in the range of 0.1 to 2.0 hp-hr/lb.

24. An enhanced woven or knit textile fabric according to claim 23, wherein the yarn is cotton spun.

25. An enhanced woven or knit textile fabric according to claim 23, wherein the yarn is wrap spun.

26. An enhanced woven or knit textile fabric according to claim 23, wherein the yarn is wool spun.

27. A method for hydrobonding woven or knit fabric materials to form a composite textile fabric, the fabric including spun and/or spun filament yarns in a structured pattern including yarns which intersect at cross-over points, the method comprising the steps of:

napping first and second surfaces of the fabric to raise surface fibers thereof,

arranging said first and second surfaces in opposing and overlying layered relation,

supporting the layered fabric on a support member, and

traversing one side of said layered fabric with a first continuous curtain of fluid for sufficient duration to effect entanglement of said raised surface fibers in said first and second surfaces,

said curtain of fluid impacting the fabric with an energy in the range 0.1 and 2.0 hp-hr/lb.

28. The method of claim 27, wherein said fluid curtain is provided by columnar fluid jet orifices having a diameter of approximately 0.005 inches and center-to-center spacing of approximately 0.017 inches, said fluid curtain impinging the fabric with fluids at pressure of approximately 1500 psi.

29. The method of claim 28, wherein said support member includes a pattern of closely spaced fluid pervious open areas aligned in a first direction to effect fluid passage through said support member.

30. The method of claim 29 wherein said open areas occupy approximately 17 to 40% of said support member.

31. The method of claim 27, comprising the further steps of:

supporting said layered fabric on a second support member, and

traversing the other side of said layered fabric in a second entanglement stage with a second continuous fluid curtain to effect a uniform composite fabric bond and finish,

said second entanglement stage impacting the layered fabric with an energy in the range 0.1 and 2.0 hp-hr/lb.

32. The method of claim 31, wherein:

said first and second fluid curtains are provided by columnar fluid jets having a diameter of approximately 0.005 inches and center-to-center spacing of approximately 0.017 inches, said fluid jets impinging the fabric with fluids at pressure of approximately 1500 psi,

said first and second support members each include a pattern of closely spaced fluid pervious open areas, respectively aligned in first and second directions, said open areas being dimensioned to effect fluid passage through said support members without imparting a patterned effect to the fabric.

33. An enhanced composite woven or knit textile fabric which comprises:

at least two fabric layers which each include spun and/or spun filament yarns in a structured pattern of yarns which intersect at cross-over points, said fabric layers including first and second napped surfaces which have raised surface fibers, said napped surfaces being arranged in overlying and opposed relation and bonded together by dynamic fluid energy through entanglement of said raised surface fibers in said first and second surfaces.

34. An apparatus for enhancing and finishing woven and knit fabric including spun and/or spun filament yarn by impacting the fabric with pressurized fluid jets, the fabric including yarns which intersect at cross-over points, and first and second sides, the apparatus comprising:

conveyor means for conveying the fabric in a machine direction ("MD") through a production line including a first enhancing station, said conveying means supporting a first support member which underlies the fabric in said enhancing station;

curtain means spaced from said first support member for directing a curtain of fluid onto the first side of the fabric, said curtain means including a plurality of densely spaced orifices which eject high pressure fluid jets;

said curtain means coacting with said first support member to entangle fabric yarns at the cross-over points, enhancing fabric cover and imparting a uniform finish to the fabric.

35. An apparatus as set forth in claim 34, wherein said fluid orifices have a columnar configuration, a diameter of approximately 0.005 inches and center-to-center spacing of approximately 0.17 inches, and impart energy to the fabric of approximately 0.1 to 2.0 hp-hr/lb.

36. An apparatus as set forth in claim 35, wherein said fluid jets have a spray pressure of approximately 1500 psi.

37. An apparatus as set forth in claim 34, further comprising a second enhancing station, a second sup-

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port member which underlies the fabric and is supported for movement on the production line by said conveyor means, and a second curtain means spaced from said second support member for directing a curtain of fluid onto the second side of the fabric, said second curtain means including a second plurality of densely spaced orifices which eject high pressure fluid jets, thereby further enhancing the fabric.

38. An apparatus as set forth in claim 37, wherein said first and second fluid curtains respectively impart energy to the fabric of approximately 0.1 to 2.0 hp-hr/lb.

39. An apparatus as set forth in claim 38, wherein said second support member is fluid pervious and has open

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areas aligned on a bias relative to the machine direction of the line.

40. An apparatus as set forth in claim 39, wherein said first and second curtain means are spaced approximately 0.5 inches from said first and second support members, said fluid jets have a spray pressure of approximately 1500 psi, and conveyor means speed is approximately 100 fpm.

41. An apparatus as set forth in claim 40, wherein said first and second support members respectively have generally flat and cylindrical configurations.

\* \* \* \* \*

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**UNITED STATES PATENT AND TRADEMARK OFFICE  
CERTIFICATE OF CORRECTION**

**PATENT NO.** : 4,967,456

Page 1 of 18

**DATED** : November 6, 1990

**INVENTOR(S)** : Herschel Sternlieb, Jodie M. Siegel, John M. Greenway

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the title page, under Related U.S. Application Data [63], "Continuation-in-part of Ser. No. 41,542, Apr. 23, 1987, abandoned, which is a continuation-in-part of Ser. No. 184,350, Apr. 21, 1988, abandoned.", should read -- Continuation-in-part of Ser. No. 184,350, Apr. 21, 1988, abandoned, which is a continuation-in-part of Ser. No. 41,542, Apr. 23, 1987, abandoned. --.

In the drawings, Sheets 1 - 17, "Figs. 1-17" should be replaced by -- seventeen (17) sheets of Formal Drawings, Figs. 1-17 --, as shown on the attach pages.

Column 1, line 53 after "twisting" insert -- . --.

Column 2, line 45, "Gilpatrick", should read -- Willbanks --.

**Signed and Sealed this**

**Twenty-seventh Day of October, 1992**

*Attest:*

DOUGLAS B. COMER

*Attesting Officer*

*Acting Commissioner of Patents and Trademarks*

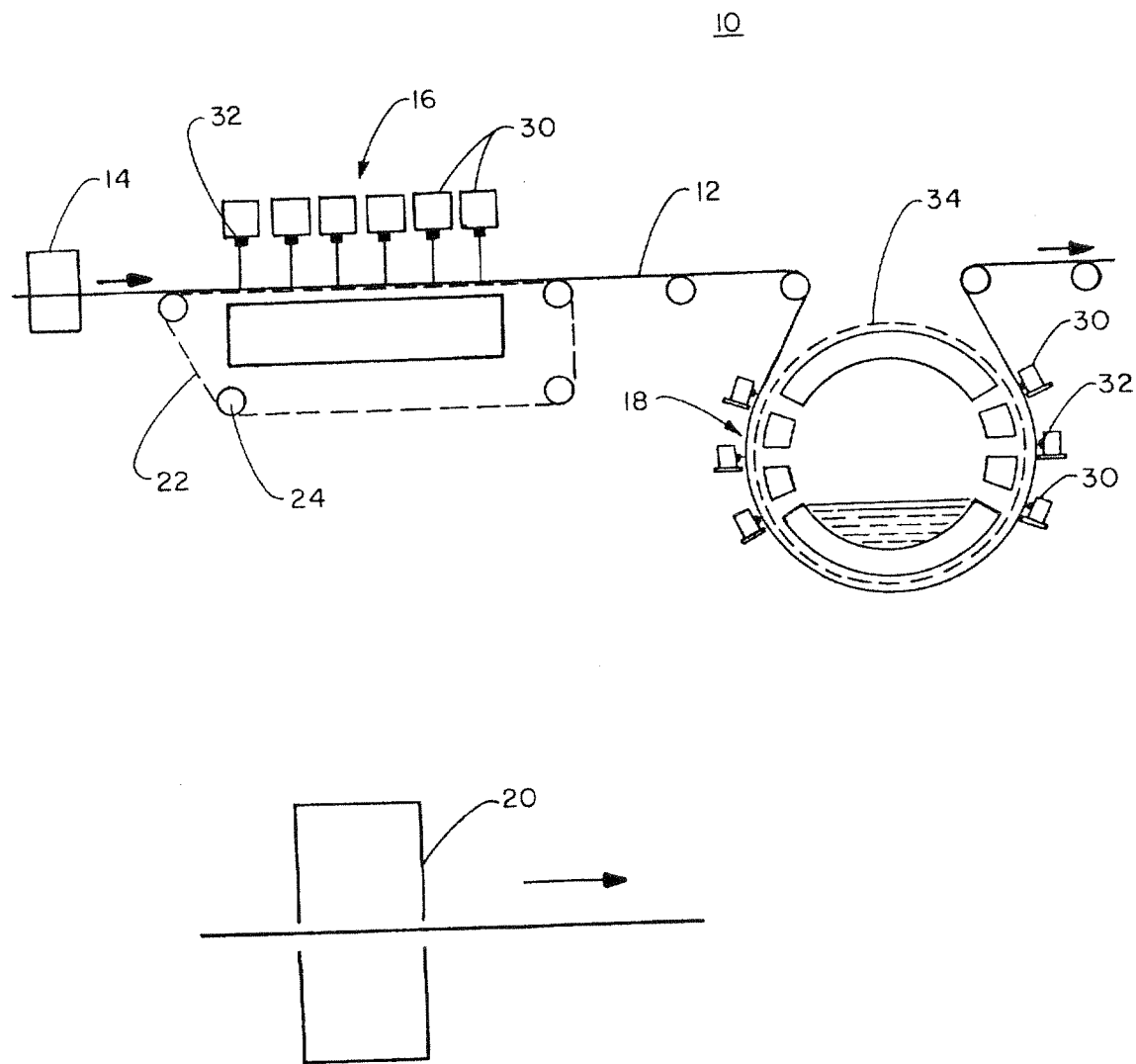


FIG. 1

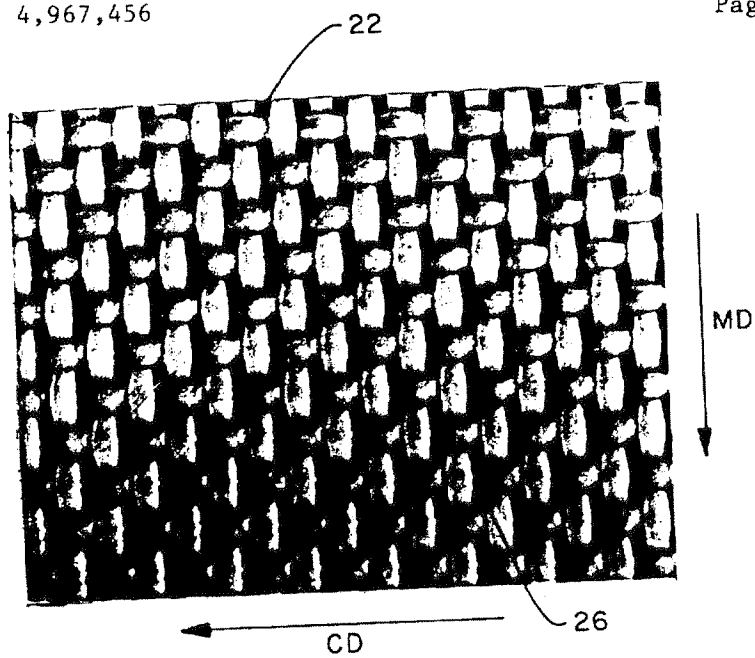


FIG. 2A

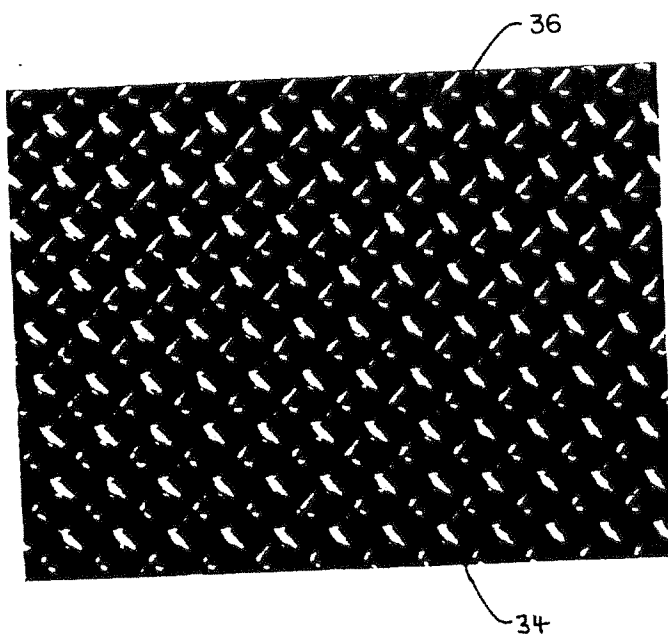


FIG. 2B

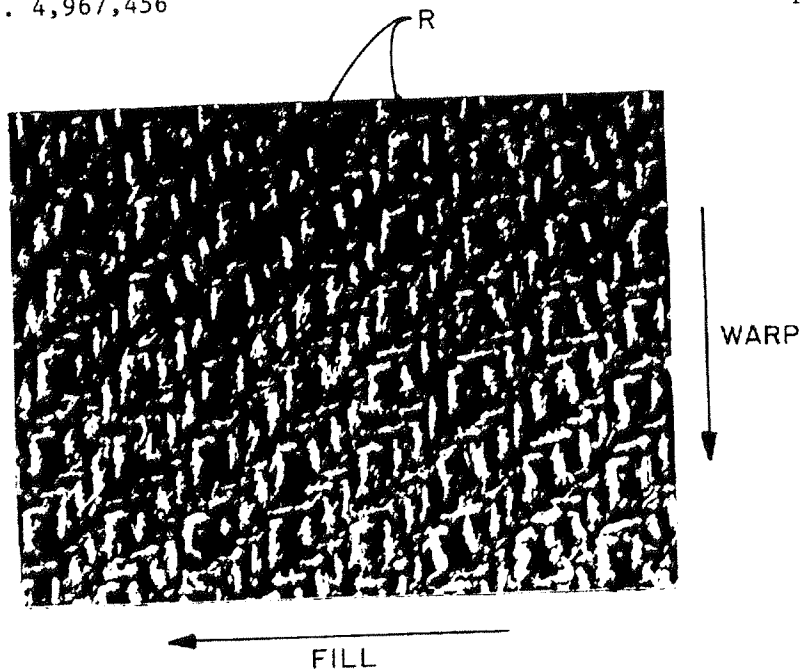


FIG. 3A

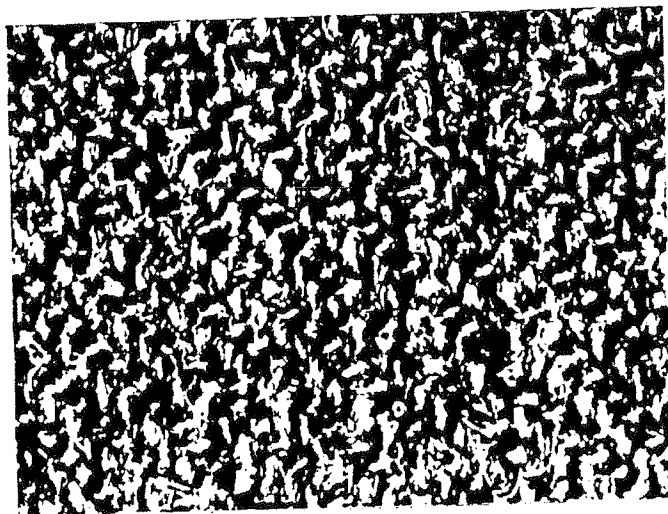


FIG. 3B

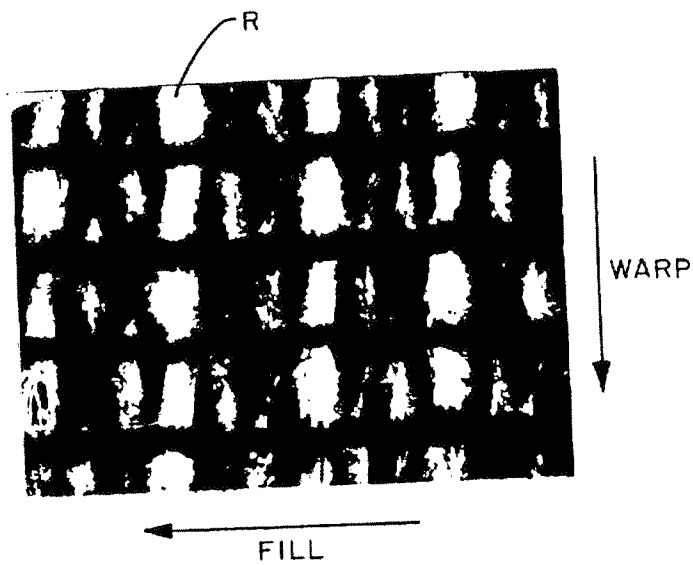


FIG. 4A



FIG. 4B

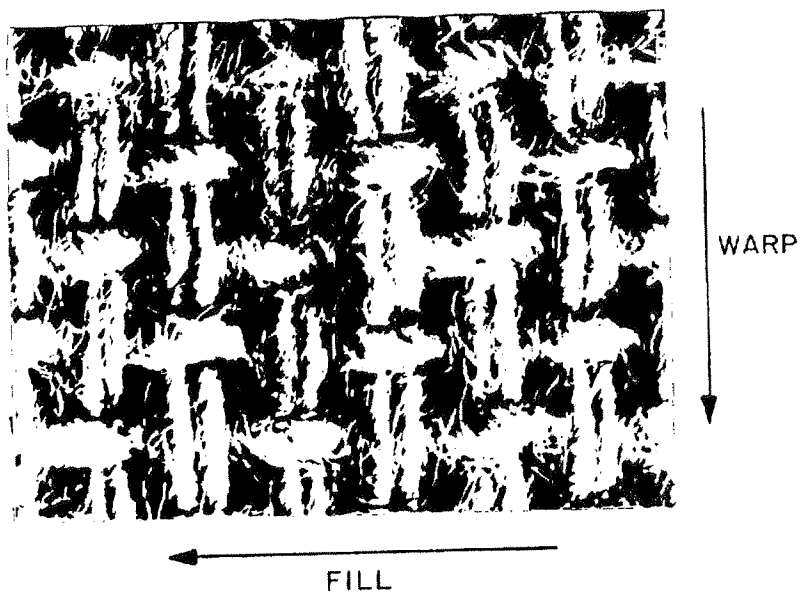


FIG. 5A

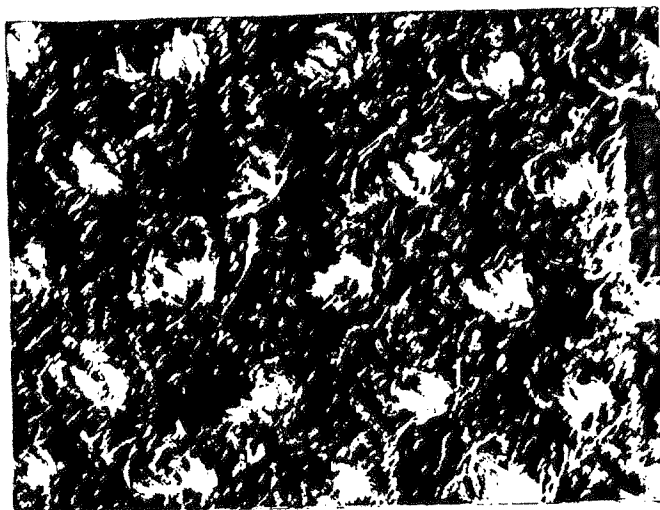


FIG. 5B

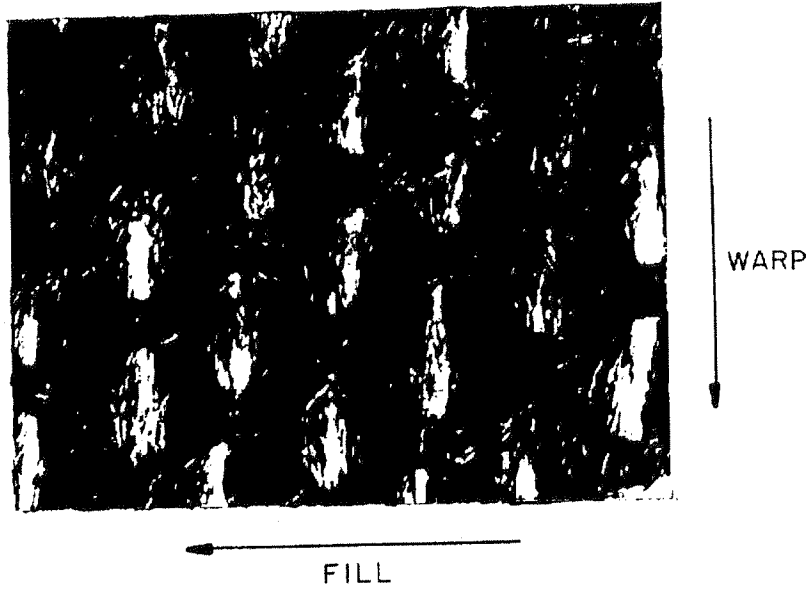


FIG. 6A

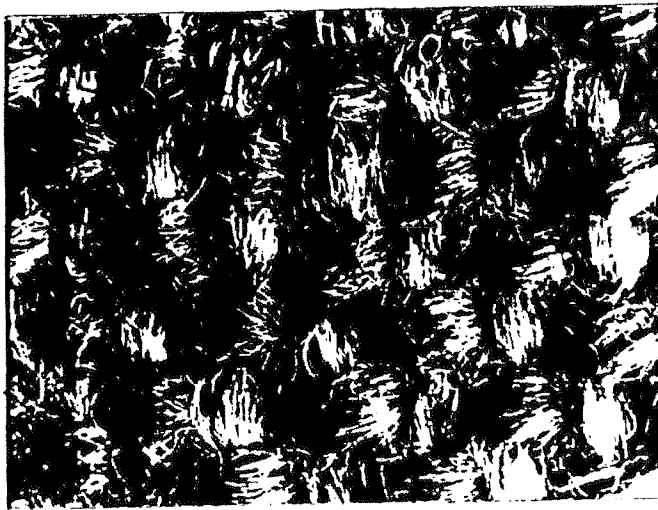


FIG. 6B

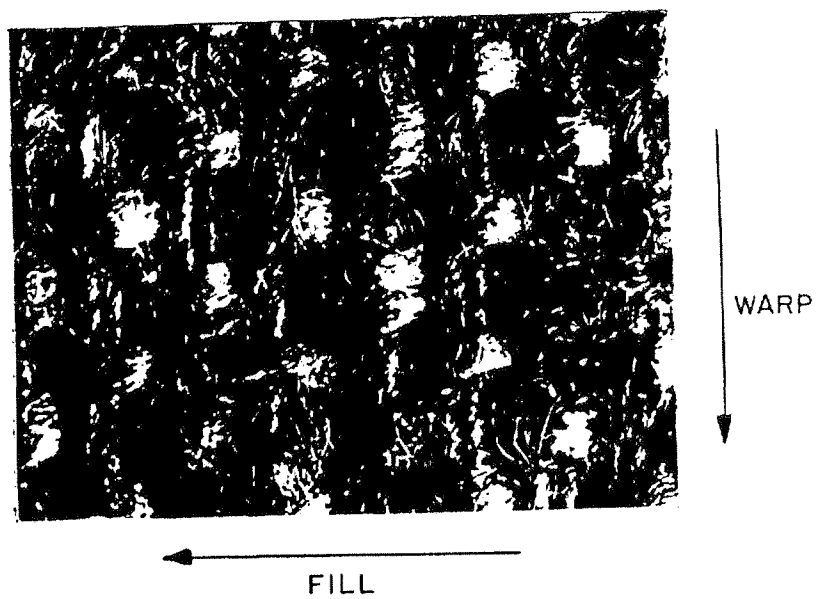


FIG. 7A

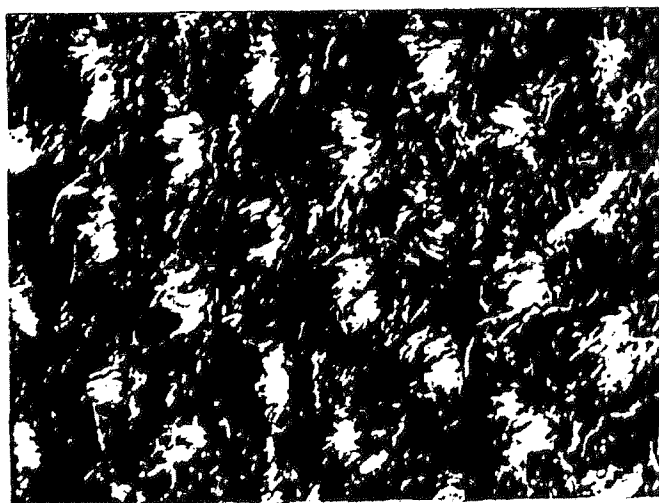


FIG. 7B

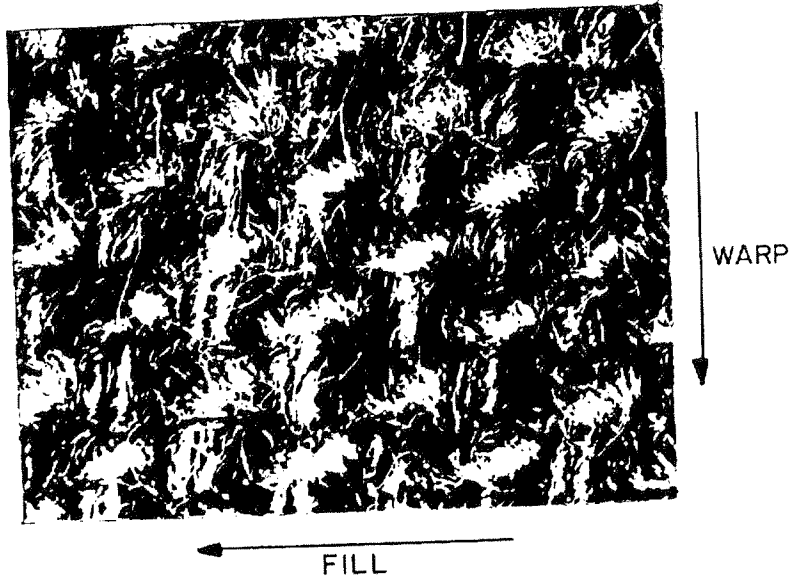


FIG. 8A

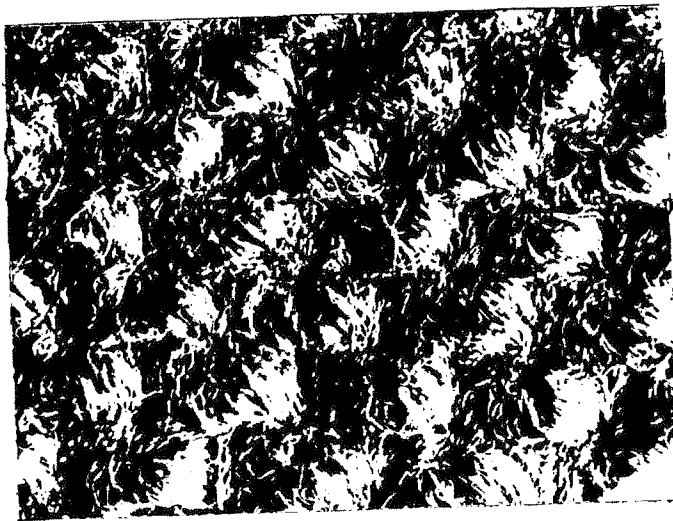


FIG. 8B

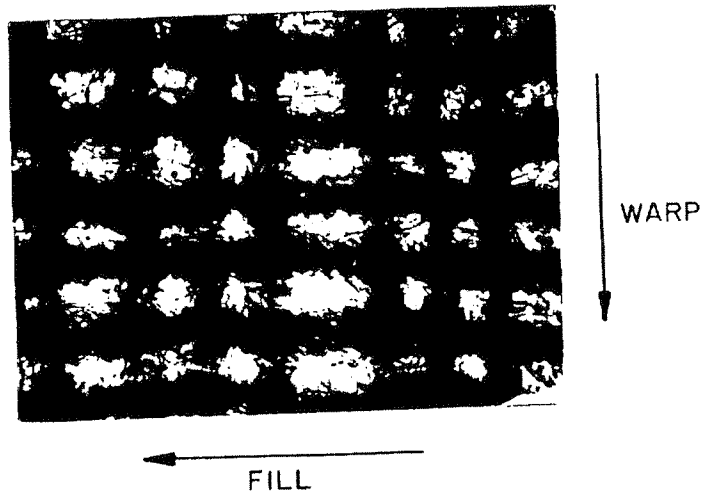


FIG. 9A

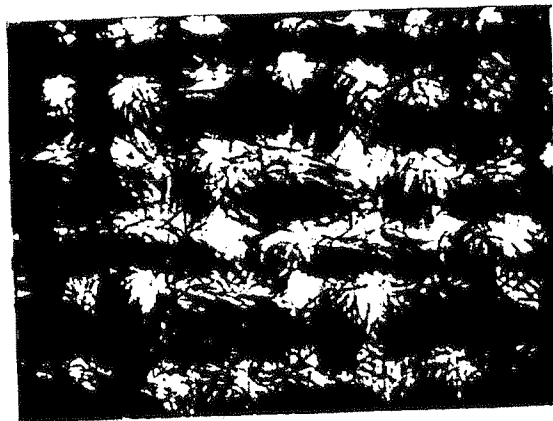


FIG. 9B

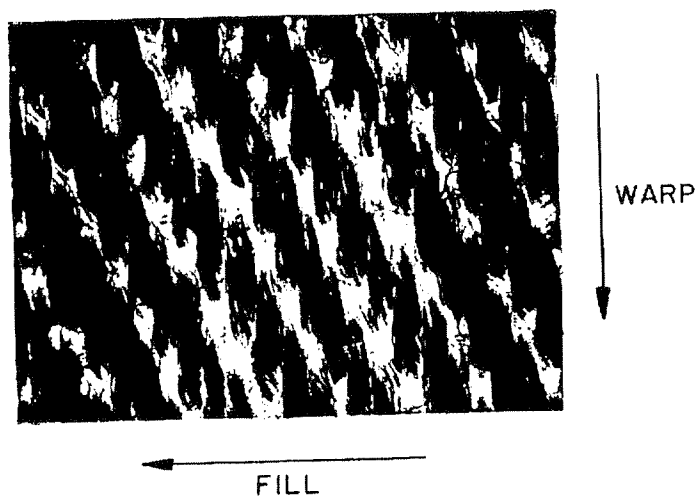


FIG. 10A

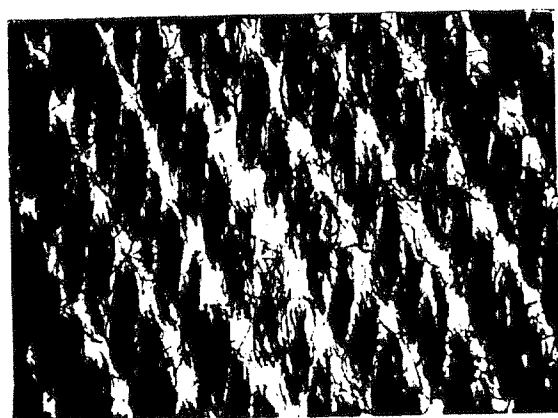


FIG. 10B

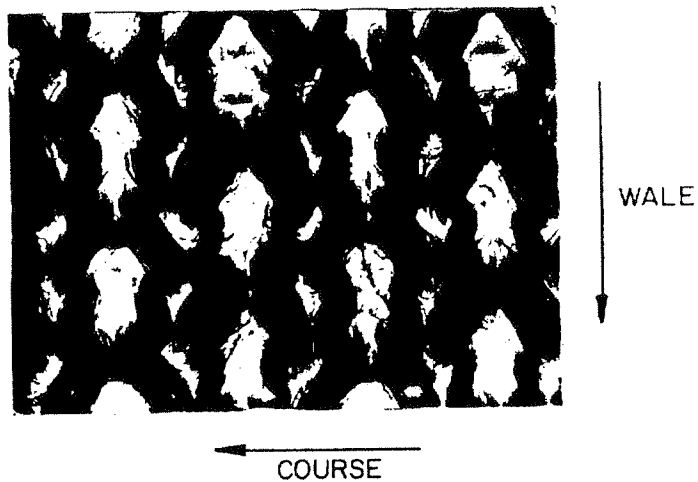


FIG. IIA



FIG. IIB

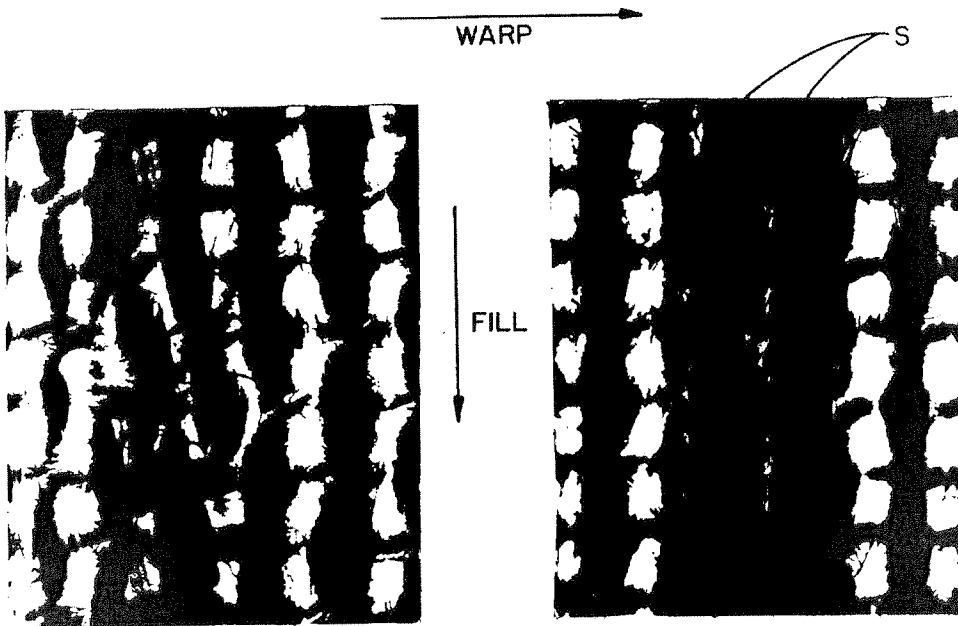


FIG. 12A

FIG. 12B

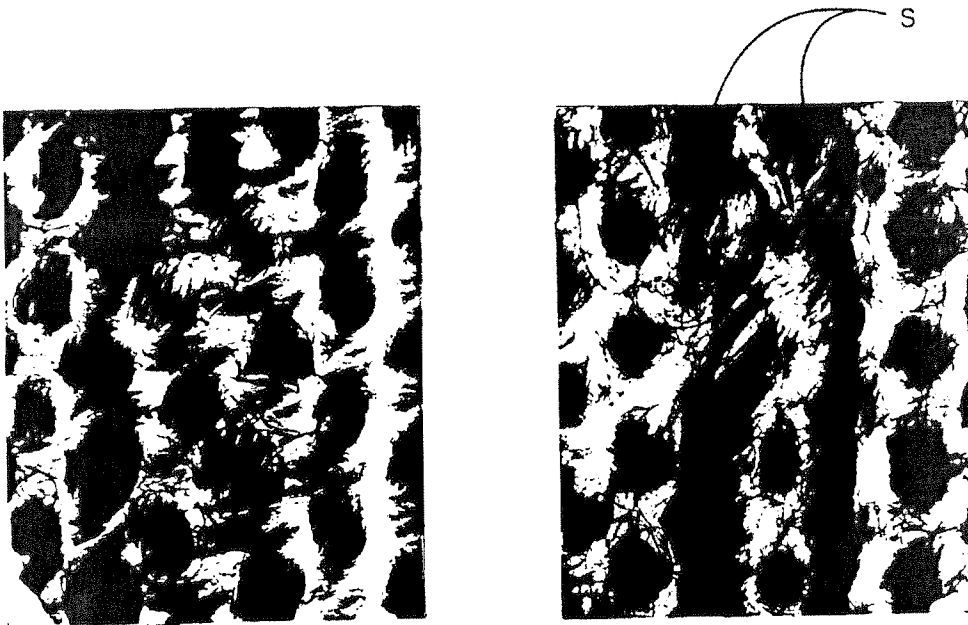


FIG. 13A

FIG. 13B



FIG. 14A

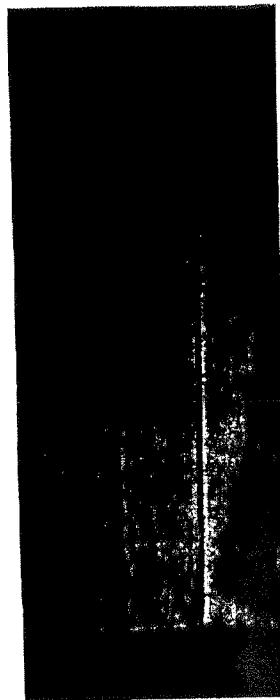


FIG. 14B

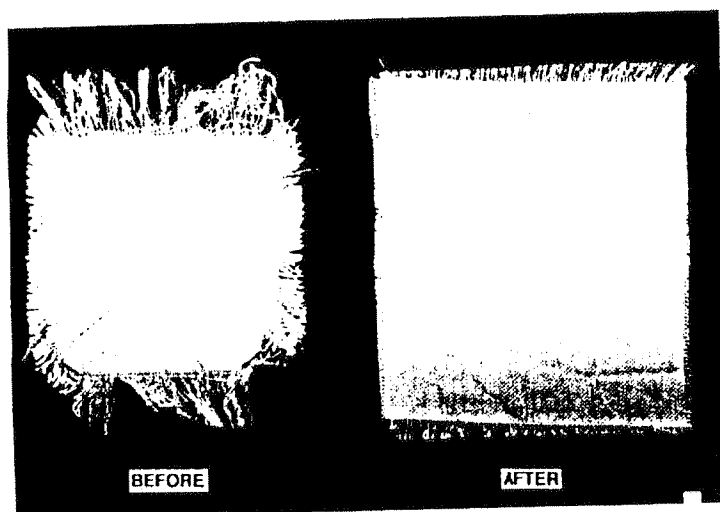


FIG. 15A

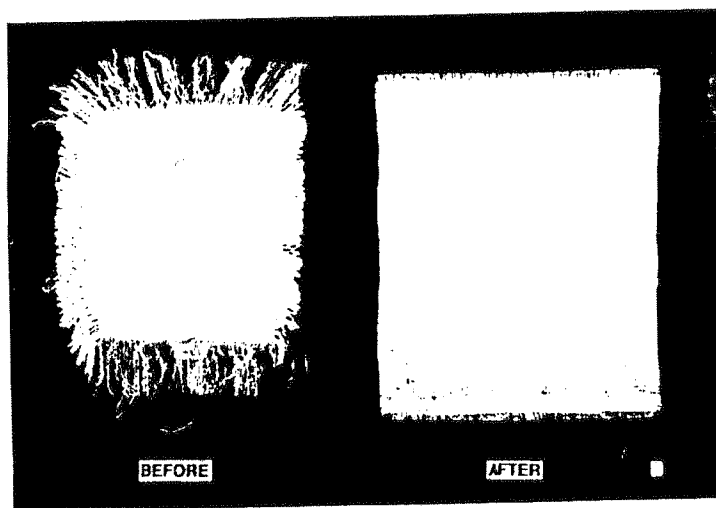


FIG. 15B

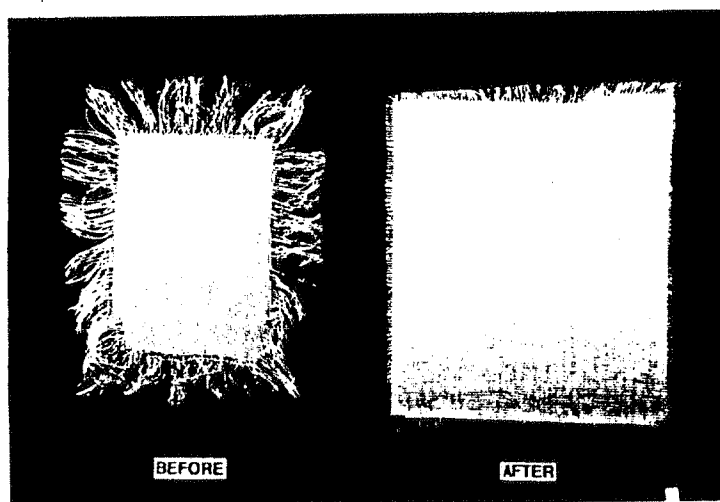


FIG. 15C

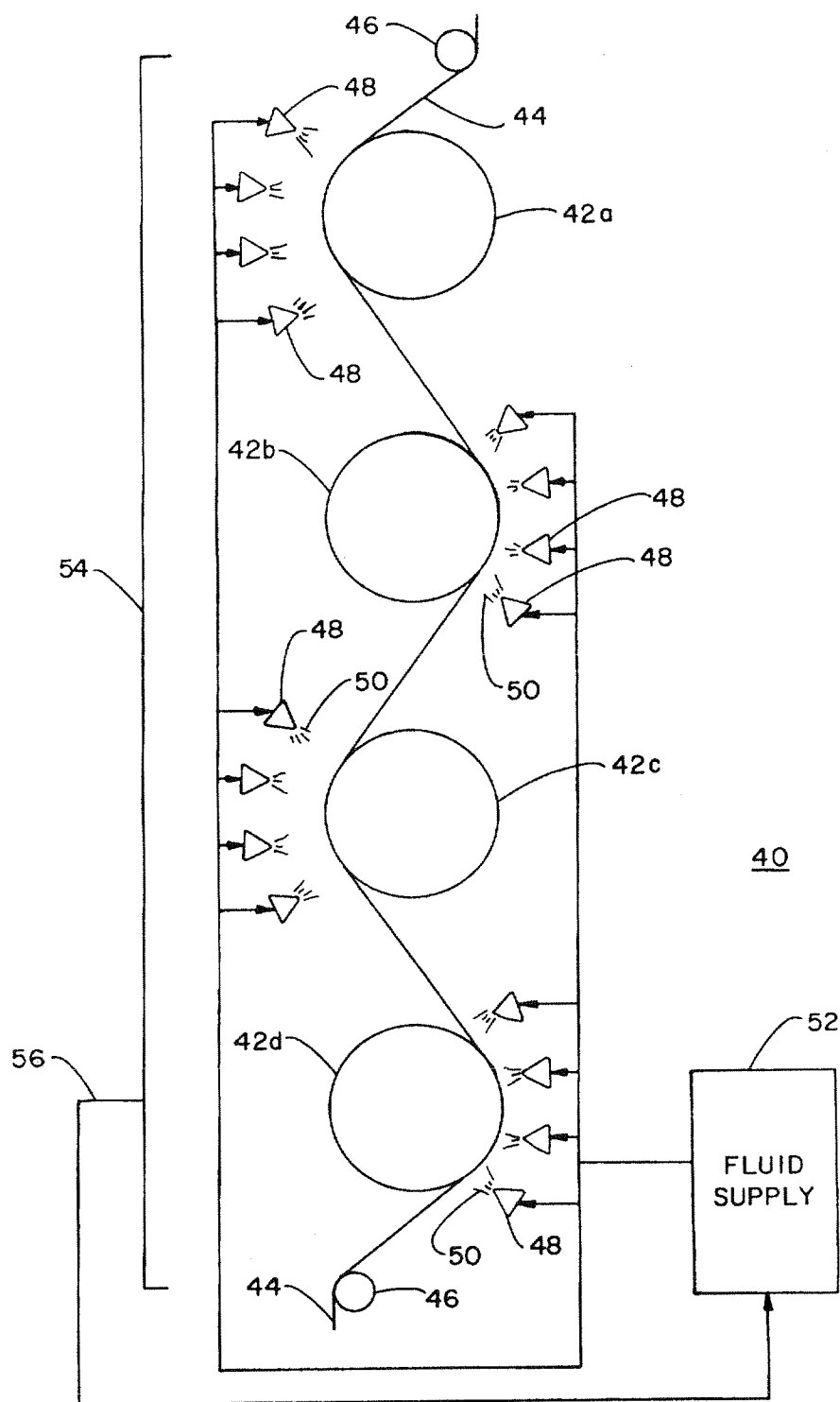


FIG. 16

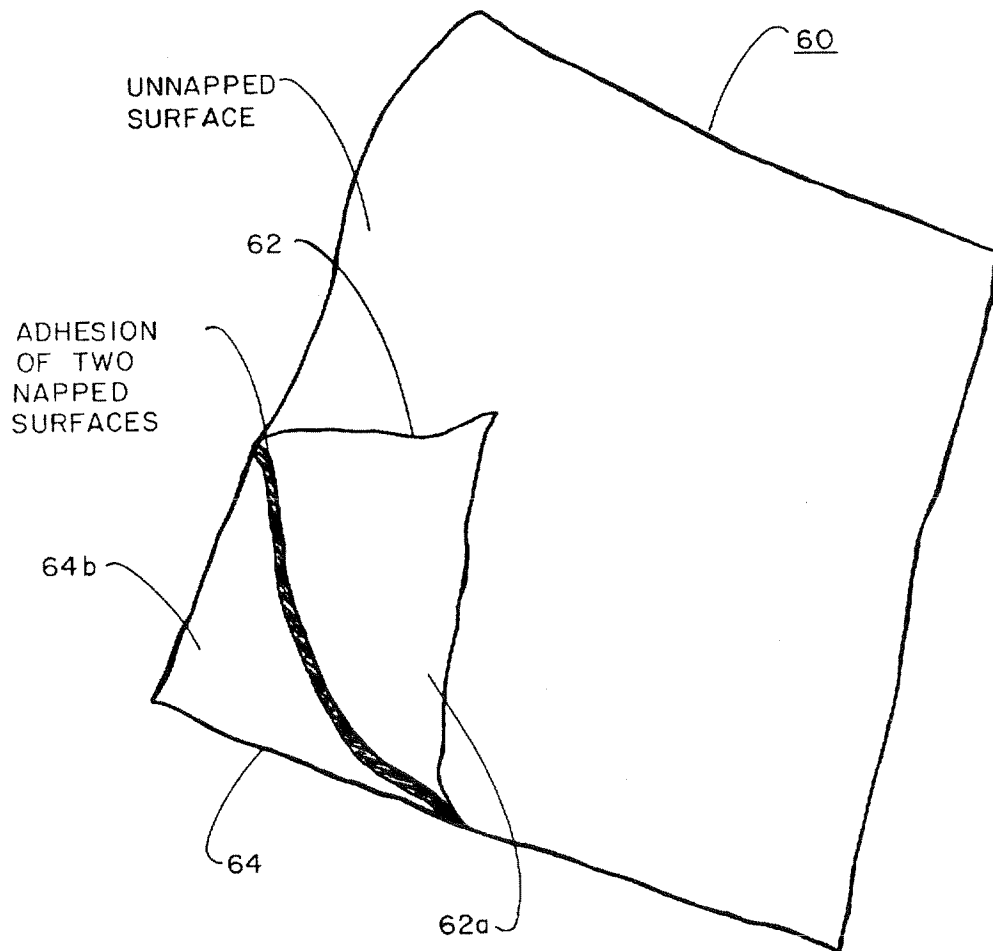


FIG. 17

**APPENDIX III**  
**RELATED PROCEEDINGS**

None